8452-65-41
TM-65-3

SECRET
SPECIAL HANDLING

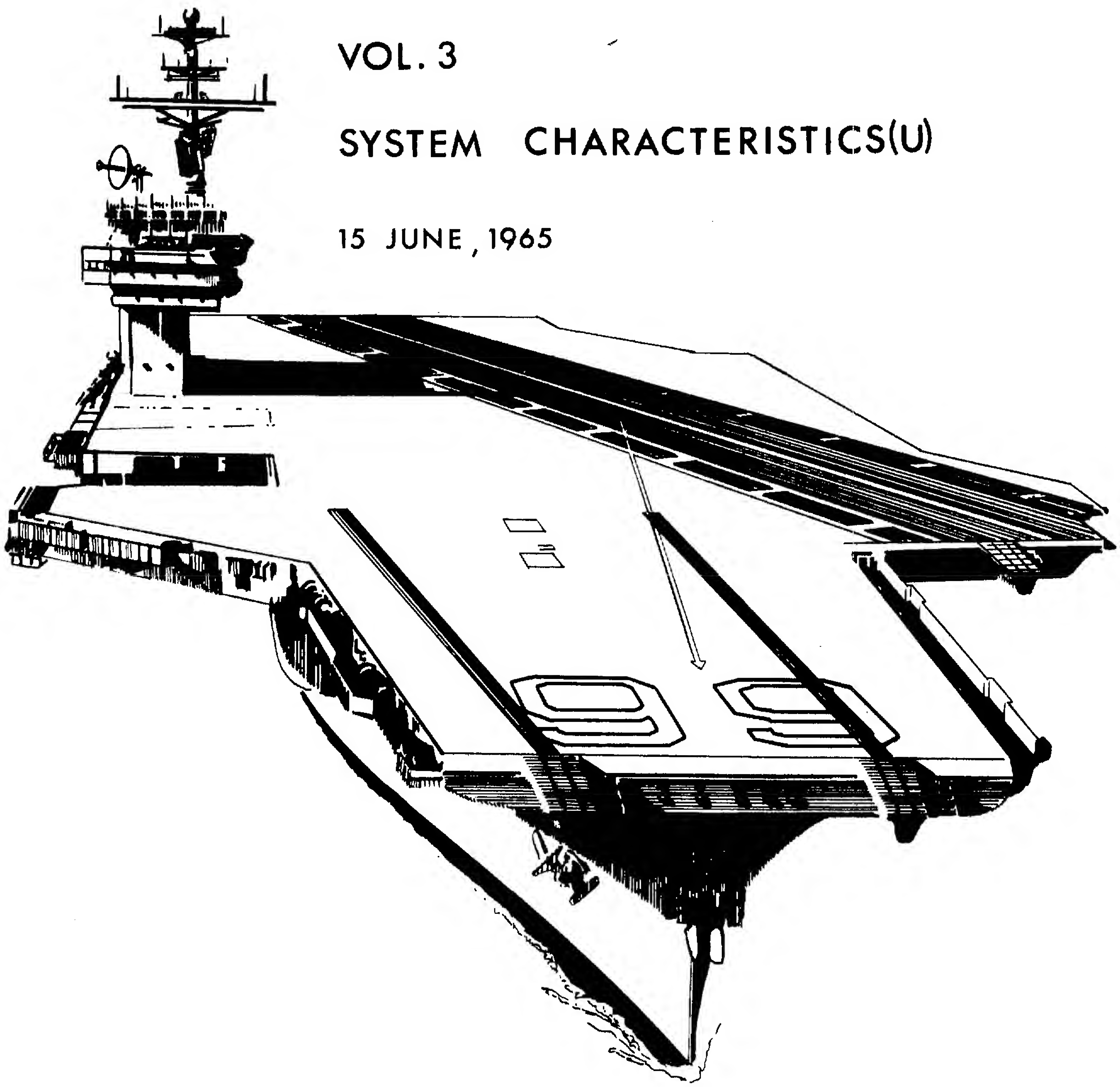
COPY NO. 1

TACTICAL MULTISENSOR RECONNAISSANCE (U)

VOL. 3

SYSTEM CHARACTERISTICS(U)

15 JUNE, 1965



SPECIAL HANDLING
SECRET

CONTENTS

SPECIAL HANDLING

SPECIAL HANDLING

FIGURES

TABLES

INTRODUCTION

A great many studies have been published in recent years discussing elements or groupings of techniques and equipment relating to multisensor reconnaissance. These documents often approach multisensor technology from the viewpoint of a single sensor specialist, and give the notion of having reached a preconceived solution to the problem at the inception of the study. A careful search of study reports available to this project team indicated that no report existed which defined and/or examined the entire range of multisensor techniques components and configurations which were possible in the current and near-term "state-of-the-art" as a basis for determining the best possible sensor/processing/reduction configuration for each particular multisensor or application.

This document has been prepared to fill the gap of information described above. The study team, made up of personnel from four of the leading organizations in advanced sensor development, felt it essential that such a document be prepared as a basis for any analysis and definition of multisensor system requirements. The organization, capability and function of components are considered in generic terms and do not relate in any way with particular devices made by the participating companies or, in fact, any company. All possible component types, component organization and data flows have been delineated and described without particular regard or recommendation concerning efficiency or sophistication.

This document, then, is a description of all possible components and component interrelationships and the associated alternatives for data format, processing sequence and flow. No attempt is made here to describe the technology; this is detailed in another section. The purpose of this document is to describe all possible elements of the multisensor system from acquisition to complete sensor record exploitation.

SPECIAL HANDLING

SPECIAL HANDLING

1. MULTISENSOR RECONNAISSANCE SYSTEMS

A current concept in tactical reconnaissance involves the utilization of many sensors for collecting information on ground targets. The underlying concept of multisensor reconnaissance is that each sensor has a special reaction to, and records information from, a different portion of the radiation spectrum. Currently, the four major categories of sensors which make up multisensor systems are photography, infrared, side looking radar, and ELINT. To these basic four should be added the visual capability of the aircrew members.

This discussion of multisensor systems will pertain particularly to high performance aircraft, although the procedures and technical discussions relating to each sensor can be extended to the use of these systems in low performance aircraft.

Currently, the radiation reflection and emission characteristics of many targets are not well known except in the visual range. This complicates the problem of interpreting information recorded in other parts of the radiation spectrum. In time, the familiarity with sensor records taken in other parts of the spectrum will probably allow as complete interpretive analysis of infrared and side looking radar as is currently available for photography. The problem of a human analyst understanding radiation patterns which he does not normally see is only a matter of training and experience.

Each of the sensors in the multisensor system has particular usefulness. Photography provides the familiar information such as size, shape, color, texture, and allows direct recognition of familiar objects. Photographic records can be made in the radiation spectrum which is near the visual range. Photographs in the infrared and ultraviolet ranges will have differences in tonal gradations from a visual photograph which is unfamiliar but, in many cases,

useful to the photointerpreter. For example, infrared photography gives some indication of thermal activity, and is particularly sensitive to infrared reflectivity loss due to decreased water content which leads to the use of infrared sensitive materials for camouflage detection where natural foliage can be distinguished from artificial by its lack of water content. Some photographic indication is also present of the temperature or relative temperature.

Infrared sensors, which are distinct from photographic sensors, can uniquely determine the temperature of a target with great accuracy. They respond to passive IR emission and thus are useful in the absence of light. Infrared will provide an indication of shape and size comparable to that found in photography. In addition, since IR sensors record thermal activity, they are useful for locating manmade objects, and in determining operational activity levels.

High Resolution Side Looking Radar depends on recording a self-generated electromagnetic signal and analyzing the target reflections of that signal. Metallic and manmade objects are highly reflective to side looking radar sensors which enables the reconnaissance analyst to locate quickly objects which are likely to be of high interest. Side looking radar also provides a mapping capability which does not depend on solar radiation thus making it useful for nighttime operations.

The ELINT (electronic intelligence) sensor is a passive reconnaissance system which simply receives records and analyze electromagnetic radiation over a wide frequency range. Since many modern ground forces are equipped with various radars and other emitters, ELINT is useful in detecting and locating these characteristic emitters by analyzing the received signal with respect to aircraft position. The type, number, and location of radars and other emitters can be determined.

It can be easily seen that each of the sensors has a unique capability. Thus, the modern multisensor concept is that of combining, on a common time base, the results of each of these sensors to obtain a far more detailed and accurate picture of ground events than would be possible using a single sensor. Figure 1-1 is a general system diagram which shows the various sensors, the operations which they perform, and their interrelationship with each other. The interconnections and interactions between sensors are laid out to indicate all of the

Approved For Release 2009/12/10 : CIA-RDP67B00657R000300200001-5

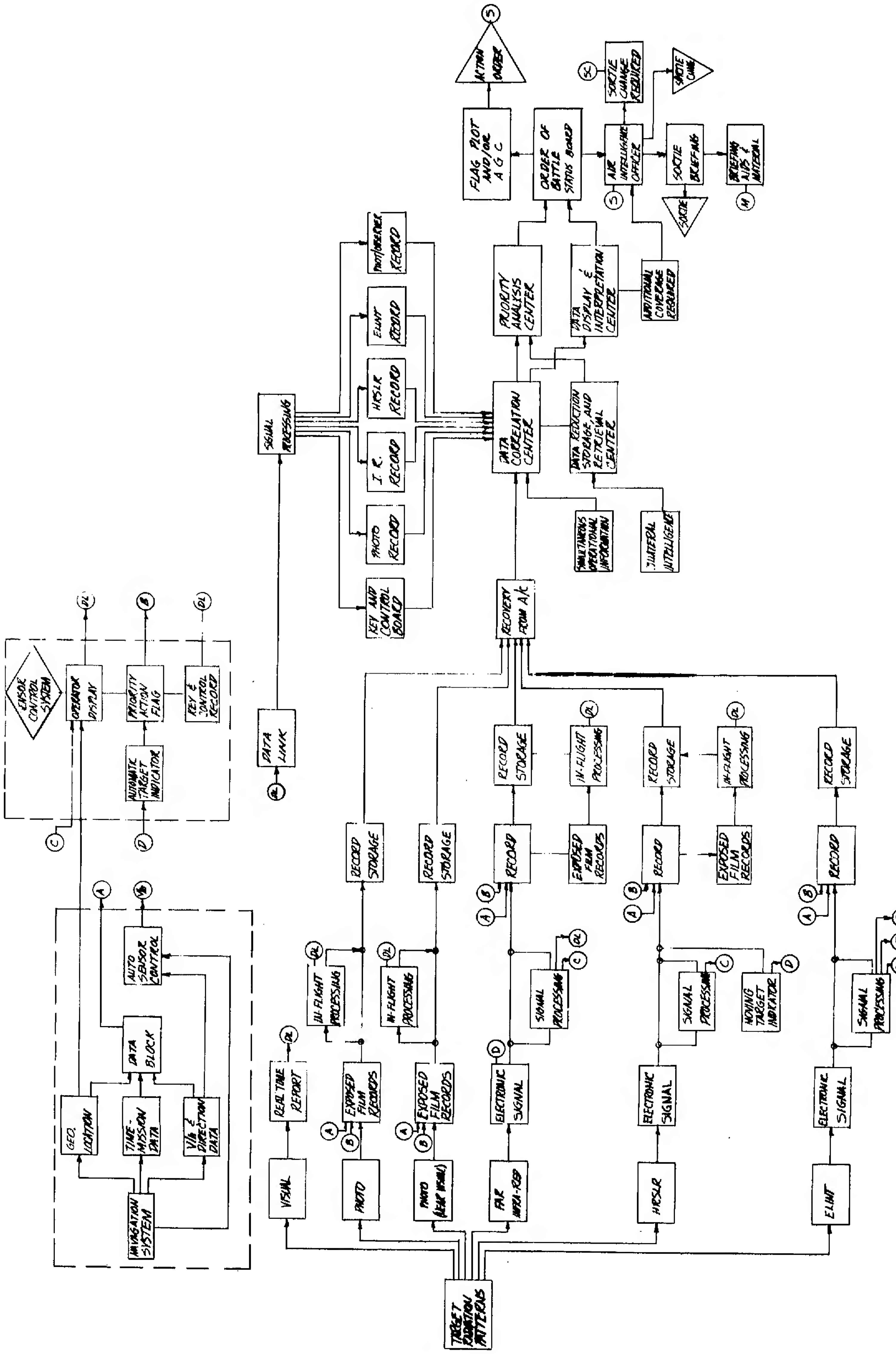


Fig. 1-1 — Multisensor block diagram.

possible changes in groupings that seem reasonable. The system diagram covers the operation of a multisensor reconnaissance system starting with the characteristic radiation patterns, either passive and active, of a given target and finishing with the action order given by a commander on the basis of the analysis of the collected information. The interplay of records and information is characteristic of any multisensor system and does not relate particularly to any current operation.

1.1 ANCILLARY EQUIPMENT AND PARAMETRIC RECORDINGS

In discussing the use of a multisensor aircraft for tactical reconnaissance, it is necessary to assume that some major ancillary pieces of equipment are available. It is assumed that a high accuracy inertial navigation system is available aboard the aircraft, and that there is provision for reading the output of that system into the data blocks of the sensor, sensor controls, and other points in the system where that data may be useful.

1.1.1 Ancillary Data

Proper operation of a multisensor system requires that certain information be available in either digital or analog form, to the various systems aboard the aircraft.

1.1.2 Time

Accurate time must be recorded at most of the sensors to the nearest millisecond, and this time should be accurately correlated at the beginning and end of the mission with those time systems in use at the interpretation station. Time is required because all of the data blocks, key records, and other devices are collated against a time base. For example, the location of the aircraft is known against a time base. Given the time base, the appropriate photograph or record from any of the sensors can be located quickly, simply by referring to the proper time on the data block associated with the record.

1.1.3 Mission Data

There must be available for use in the data block systems and wherever else required, information regarding the day, month, year, the aircraft identification, the pilot's name, the mission identification and any other prominent records associated with a particular mission. These should be available as digital signals for inclusion in the data block or other signal systems inherent in the operation of the sortie. It would be useful, for example, that this mission data be provided at intervals as a key on data link transmissions to identify the particular aircraft issuing a report.

1.1.4 Geographic Location

One of the parameters against which a record will be keyed for analysis is the proper geographic location of the aircraft at the time the record was taken. It is assumed that the geographic location supplied by the inertial navigation system will be accurate to at least a tenth of a mile in latitude and longitude at any time during the mission. It is possible that some of the display and auxiliary systems associated with the multisensor aircraft can be fed into and update the navigational equipment by reference to known major geographical checkpoints during the mission.

1.1.5 Velocity, Height and Direction Indications

In addition to the navigation equipment, it is expected that radar altimeters and speed indicators as well as conventional barometric altimeters and air speed indicators will be available. The radar altitude and velocity measurement would provide the proper velocity and height correction normally needed to operate the image motion compensation modes in photographic and infrared systems. This information is also required in the analysis and signal processing of the high resolution side looking radar and the ELINT signals. It also is necessary to know the compass heading and direction of flight of the aircraft to a high degree of accuracy in order to compute effects of, say, crab angle on the high resolution radar, and to provide location corrections to devices connected with the ELINT and infrared photographic sensors.

1.1.6 Automatic Sensor Control

The information generated by the velocity, height and direction systems should be used in conjunction with "black box" equipment which will provide automatic sensor control and corrections of the V/h ratio and correction of crab angle in IMC. Those parameters of the side looking radar and ELINT which require active control regarding velocity, height and direction on aircraft during exposure of their records will also be automatically corrected.

1.1.7 Data Block

A data block must be imposed on all records which indicates the numerical value of the important parameters in data reduction. A standard military data block is in existence which contains the proper information. It is suggested that in addition to the information already in the standard block, that the actual speed of the aircraft with relation to the ground be added to an unused part of the data block. The standard block records radar altitude, longitude, latitude, GMT time, the pitch and drift of the aircraft, the aircraft heading, barometric altitude, the side looking radar mode, the sensor identification, sortie number, aircraft identification, the year, the month, and the day. Currently, it is in a man-readable digital data system which has been proven operationally adequate. With the addition of aircraft speed, all of the information necessary to automatically reduce any record in computer assisted techniques will be available. This data block should be impressed on every frame of a frame record, and periodically at timed intervals along the margin or near the margin of any strip records, such as are produced by strip cameras, panoramic cameras, side looking radar, and ELINT systems. The ELINT system will require data conversion to a digital sequence code so that it may be impressed properly on a magnetic tape specifically used for recording the ELINT information. However, infrared, side looking radar and the photographic sensors will employ the impressed digital data block which forms the visual image on the final film records that are associated with each of those sensors. If the infrared sensor, for example, uses magnetic tape as an auxiliary recording medium, the digital code formed for use on the ELINT system will be impressed on the infrared tape as well.

1.1.8 Operator/Observer Displays and Functions

The display of information to the operator/observer of the reconnaissance equipment in the multisensor aircraft could increase the usefulness of a multisensor system. Briefly discussed earlier was the fact that the pilot of a high performance aircraft will be occupied with his vehicle, but that time is available for a crewman aboard such an aircraft to perform tasks involved with the operation and utilization of the sensor inputs from the multisensor system. Currently available to the operator is an optical viewfinder which produces several valuable pieces of information. The observer is able to visually read out drift angle, and to calculate the V/h ratio information, should the automatic systems be inoperative. The optical viewfinder locates a nadir and vertical camera principal point, shows the vertical camera format, provides a traveling grid for V/h determinations, provides for a forward oblique format indication, shows the track line of the aircraft, and can be used for updating navigational information. While the information available in the optical viewfinder is certainly of interest to the observer and operator, it is possible perhaps to provide him with a display which involves automatic location and identification in some cases, of interesting priority targets. It is genetically possible to say that a display could be provided to the operator which would indicate on it against a geographic or other display device, the location of moving targets as determined by the side looking radar, hot spots as determined by the infrared systems, and the location of ELINT emitters as determined by the ELINT system. There is no information currently available from the photograph, which is a definite target indicator, separable from the background noise automatically without the interference of an operator.

It is reasonable to suppose that the electronic signals generated by the infrared sensors, high resolution side looking radar sensors, and the ELINT sensors, could be fed to a system which would automatically indicate previously defined threshold information.

The location of items of interest may be automatically indicated but it is not probable that such a system can absolutely identify the type of target.

The following examples of the ability of an automatic target indicator are given. It would be relatively simple to threshold at a given temperature above

background and record the location of those hot spots and signals which exceeded that temperature. Such an automatic system could give the cross-track indication in conjunction with time. This could absolutely identify the location of the hot spot with regard to other records being made by other sensors, for correlation at a later time. In this way, the location of thresholded targets from an infrared standpoint can be pinpointed on the photo records, and the high resolution radar records for comparison at a later time. Secondly, high resolution radar can be processed so that it produces a moving target indication which can be recorded and indicated in near real time. Such a moving target indication could be displayed to the operator through the automatic target indication system so that he might be able to discover fleeting targets, which are of high interest in a tactical situation. Having the moving target indications displayed before him over a finite area would allow him to make counts, work on route surveillance, and in general perform a low level of interpretation which could be highly useful in working the final records for interpretation when the aircraft returns to its base. It is altogether possible that a high density of moving targets at a location where they were not otherwise expected, could be a priority piece of information which would require quick command reaction.

ELINT equipment will be able to locate and identify emitters in a very large area and their location and identification on the operators display screen might be a very important factor toward his survival and effectiveness during a mission. The operator display system would require an input geographically locating the aircraft. It should have an indication of those things discovered by the automatic target indicator and sensor identifying symbols, so that the operator can easily tell the source of the signal. It is also possible, using the electronic signal from the infrared sensor, to impose on the same display screen, an infrared map image of the local area. Using this map it would be possible to perform navigational updating against the computed location of the aircraft on an available hard copy map.

1.1.9 Automatic Target Indicator

The general problem of too much information from too many sources has complicated the analysis problem of multisensor reconnaissance data. The concept of displaying key information, that is, information which refers to objects of

high probable interest, has been described in the previous section. It is necessary, in order to work with such a display system, to have a method of determining what object is interesting out of a large number of features which will be present in the records from the multisensor systems. Since there are no distinguishing characteristics in the photographic records which are currently subject to automatic identification; no attempt is made in this discussion to conceive of a system to process visual spectrum information. However, the same categorical qualification does not apply to infrared, side looking radar, or ELINT. Since the characteristic of an infrared sensing system is that they are capable of determining the temperature of an object or terrain feature as well as its emissivity in certain wavelengths, infrared records are susceptible to automatic screening for objects of high interest. In general, interesting objects can be defined as those which have a higher temperature, or which are markedly different than their surroundings as seen in the infrared spectrum. Since the output of infrared sensors is an electronic signal, that electronic signal can be screened by automatic thresholding devices which give an indication when the signal exceeds given and preselected threshold as far as temperature or emissivity is concerned. Thus, an automatic target indicator for infrared can be conceived. It is obvious in such a system that a false alarm rate which may be as high as 50 percent will be generated, however, the correlation of the automatically processed infrared signal with the side looking radar and ELINT signals automatically processed, can give an alarm rate which will far exceed the normal expectation for locating targets of interest automatically.

The high resolution side looking radar, which also generates an electronic signal, has inherent in it the ability to locate a moving target which is a radar reflector. Since the side looking radar does not depend on natural radiation but generates its own signal and analyzes the reflective returns, such characteristics of that return, such as doppler shift and location can be automatically processed to give an indication that a reflector is moving, give its direction vector, and in some cases its speed when the speed is relatively high. Working with an aircraft moving at Mach 1, a moving target on the ground whose directional vector is properly oriented with respect to the radar beams, can be detected when moving at as low a speed as twenty miles per hour. Below that

speed, an indication that the target is moving will be made, but its speed and vector analysis will be limited and inaccurate.

Dealing with the ELINT portion of the multisensor system, the ELINT itself can be so configured as to automatically process the incoming signal, which is of course extremely wideband, and make a comparison against fixed identification patterns. With proper computing equipment which can be airborne, the ELINT system can determine the location of, and identify an emitter as to its probable type and activity level.

It can be seen that these three sensors, each generating an electronic signal which can be automatically processed, operating in conjunction, can develop information which will ease the problem of screening the image information which is recorded by the infrared system and the photo system, as well as by the side looking radar. By using what we have called the priority flag or key system, it should be possible to reduce the time required for scanning the records from a multisensor mission, so that a high degree of probability can be maintained and targets of high interest will be looked at and detected first.

The priority flag does not presuppose that the target has been identified or is indeed a tactical target, it simply indicates that this is an area in which a higher probability of locating targets of interest exists.

1.1.10 Priority Flag or Key System

The automatic target indicating system previously genetically described has as its output, a signal which locates a target on the geographic grid and identifies it as coming from an infrared, side looking radar, or ELINT. The identification as to what sensor has discovered this high interest area, and the potential identification of it, as with ELINT can be reduced by an automatic target indicating system to a digital word which can in turn be impressed on each of the records. Therefore, the photographic, infrared, side looking radar and ELINT will contain an indication to the analyst that this is an area which should be looked at particularly as containing information which may relate to a tactical target. Since the information is in digital form it can be fed into an electronic display system for the operator, it can be recorded on a suitable

multichannel tape recorder, or it can simultaneously be transmitted over a real time data link to enable a priority analysis group at the reconnaissance center to predetermine which areas of interest they will scan first on receiving the total sensor record package from the aircraft.

As previously described, the operator/observer onboard a multisensor aircraft can have a display which provides him with a readout of those target areas which may have a high probability of containing a tactical target of interest. He will have indications of moving targets and identification of ELINT emitters. It is entirely possible that the operator will be able to provide some interpretation of activity levels which may be of interest to the Air Intelligence Officer back at the Interpretation Center. Therefore, it is reasonable to expect that the operator/observer will need the capability of providing a real time report on his findings, and it is suggested that this could be either a voice transmission or a digitally coded simple keyboard communication system. In any case, the real time report could easily be transmitted back over a low bandwidth data link which is not limited by horizon problems. This report should be simultaneously recorded for inclusion as part of the multisensor system package of records.

1.1.11 Communications and Data Transmission

One of the real problems which face a multisensor system and the interpreters is the problem of timeliness. It is possible in the current state-of-the-art to conceive of a multisensor system which will, in real time or near real time, transmit back over a data link all of the information which the system is gathering. The major problem in this area is a bandwidth limitation, in that the bit rate of the information being accumulated by a multisensor system is extremely high, ranging upward of perhaps 200 megabits per second. It is difficult to realize that the amount of information being generated by the collective sensors in a typical multisensor system is not subject to real time data transmission. One can, however, consider degrading the quality, or ground resolution of the input from the sensors and relaying back degraded information on a real time basis. The photographic resolution is commonly between 20 and 200 lines per millimeter. It is possible to transmit on current data link systems about

200 lines per millimeter from 5-inch aerial film. This requires a system which scans line by line and converts the scanned image into electronic signals processed serially. This type of system requires bandwidths of between 5 and 10 megacycles which is about the limit of current working technology. With sufficient power and proper antenna design, microwave systems can be designed which will allow between 50 and 100 megacycles real time transmission, however, these systems become bulky and heavy and are subject to distance degradations. Microwave systems in general are limited by horizon, in that they require straight line transmissions. If it were possible to reduce the bandwidth of the data required for transmission, it is conceivable to work with a narrower bandwidth and transmit coded or condensed information. A typical voice transmission system would be considered a narrow bandwidth transmission link. Much greater utilization of the bandwidth could be made by simply coding the data which was required for transmission. A detailed analysis and description of those current techniques available for utilization of data links will be found in the appendix to this document. Tracing the target radiation patterns through the multisensor network, the following items are probable subjects for transmission over a data link; first, the real time report from the visual observations, the operator's impressions and reports of either those scenes which have been seen directly or those things which have been displayed before him on the optical viewfinder or the operator's display system.

The next records which are subject to transmission over the data link would be the inflight processed photographs. The photo systems could be producing a number of feet per minute of processed photographic emulsions and passing these transparencies over a scan system and flying spot scanner whether they be negative or positive. An electronic reproduction of the photograph can be made and transmitted over a wideband data link. Depending on the number of simultaneous photographs, the requirement for bandwidth on the data link may be taxed severely.

The infrared signal coming from the sensor is already an electronic signal, and after suitable signal processing can be directly relayed over the data link. The signal may also be recorded on magnetic tape, and by suitable degradation processes a low resolution image record can be read directly from the tape over the data link. The original IR signal could be used to provide a filmed image,

much like the photograph, which when processed from the IR system, can be read out in a system similar to that used for the photographic readout. In this way an IR image could be transmitted from the processed film record made by the infrared equipment. The bandwidth requirement for infrared varies from about 1 megacycle to about 3 or 4 megacycles for transmission of the image.

The high resolution radar, which after suitable signal processing generates an exposed film record which may be inflight processed, has a low data rate when considering the comparable rates from the other sensors. High resolution radar would require a readout system similar to that used for the photographic reproduction, but since the film rates in a side looking radar are quite low and the resolution elements are reasonably large, data rates can be expected to be about 1 to 2 megacycles.

ELINT records, which will be normally recorded on magnetic tape and signal processed, will produce a tape which requires about 1 megacycle bandwidth to transmit the processed data.

Thus, it is possible, using a variety of systems ranging from flying spot scanners and line scan systems, for those records which are photographic transparencies, through direct reading electronic systems, to transmit in real time, or near real time almost all of the information collected by the sensors on a multisensor aircraft. The penalty of course, is that there is bound to be some degradation, especially in the photographic records, from the quality which is collected by the various sensors on the aircraft. Another penalty would be the excessive weight and volume required for the data link to process and transmit such a large amount of data. The data handling problem at the collection end is just as large, requiring that an image conversion system be provided for each channel. This would mean that an image converter would be required for the infrared, side looking radar, and for every photographic record which was sent, plus some means of recording the ELINT and visual coded information as well as the priority flag data, geographic location, time, and many other parameters which must be relayed over the data link to tie together the information in a workable form. However, it can categorically be said that there is the possibility of relaying over a data link on a line of sight, all of the information collected by the multisensor system, although somewhat degraded for photographic and infrared sensors.

1.1.12 Signal Processing

The problems involved with receiving the information transmitted over a data link can be extremely complex. One problem would be the necessity for a relay system, possibly a relay aircraft, when the multisensor mission is flying at a low altitude some distance from the reconnaissance center. Since the wide-band data link must operate over a line of sight, there is, of course, the potential of using a relay aircraft which would receive the transmitted signals from the reconnaissance aircraft, and relay them to the interpretation center. The use of such a relay system would provide wider coverage, and wider range for the aircraft engaged in the actual reconnaissance. A narrow bandwidth data link is not plagued by a line of sight problem, and some of the key records or voice communication would not be limited by the horizon problem. For the moment, let us assume that the signal transmitted by the reconnaissance aircraft has been received directly or relayed by means of suitable aircraft or relay stations to the reconnaissance center. As previously indicated, the sorting and reproduction of the data coming over a real time data link presents a problem. Line scan systems working in reverse can be utilized to provide a photo record of the transmitted transparencies, and the infrared and side looking radar record. A separate recording and reproduction station must be provided for each channel being transmitted; therefore, there would be at least two photographic records, an IR record, and a side looking radar record being reproduced if the total spectrum of the reconnaissance system were being relayed. In addition, magnetic tape records would have to be maintained for the priority flags, the ELINT records, and the pilot/observer reports. All of these systems would have to be collated by the automatic readout of appropriate data blocks and correlation of time signals. This presents a complication in regard to the receipt of the information, which as previously noted will be somewhat degraded in quality. As an alternative the original records could be recovered from the aircraft, although a slight time delay must be accepted since record recovery can not take place until the aircraft has returned. Whether or not the slight time advantage gained by transmitting the records in real time is of sufficient importance to justify the tremendous equipment complication is not a matter of this text. However, it should be noted that another mode of operation of the data link does exist which can be potentially useful. The data link can begin to transmit

stored data after the aircraft has finished its actual reconnaissance runs, and while it is involved in the long return to the interpretation center. This will provide a somewhat shorter time advantage, which may be of prime importance during a critical situation.

1.1.13 Ground Handling

The previous sections have discussed the problems surrounding the collection and processing of information in a multisensor reconnaissance aircraft. Up to this point, we have traced through the various reconnaissance sensors, the path of target radiation patterns as they are collected, handled, processed, and relayed, eventually to arrive at the aircraft carrier or reconnaissance center. It will be assumed from this point that all of the records in all forms are available and the following discussion will deal with what we term the ground handling of the multisensor information from the time that it arrives at the reconnaissance center until it is in a useful form for a decision making command system. The records collected from the multisensor aircraft must now be collated with a total picture of battlefield reconnaissance. The information must be handled through one of several possible paths, through four basic operations. These are first, a Data Correlation Center, in which the information from this particular mission and all other missions carried on simultaneously can be sorted out and those records which are of high importance can be priority processed. The Data Correlation Center will normally be the responsibility of the Air Intelligence Officer and it will be his decision and his option to select those areas of records of maximum importance for immediate interpretation. From the Data Correlation Center, information may be passed to a Priority Analysis Center where a first rough cut at those items of importance can be taken. The information may be passed to a Data Display and Interpretation Center for detailed interpretation. From either the Priority Analysis Center or the Data Display and Interpretation Center, the information in interpreted form calling out Orders of Battle, would be passed to an Order of Battle Status board for interface with the decision making and command organizations. As a support organization for the Priority Analysis Center and the Data Display and Interpretation Center, a Data Storage, Processing, and Retrieval Center will be necessary. This area will store collateral intelligence from other sources and will

act as a library, receiving interpreted information for future use. From the Order of Battle Status board, information will pass to the Air Intelligence Officer who will be responsible for briefing reconnaissance and strike crews. The Order of Battle Status board also interfaces with the flag plot or command post, which initiates the action orders which will in turn eventually change the target radiation patterns, completing the total cycle. The operation of the Reconnaissance Center has been laid out in detail because of the tremendous complexity of the operation involving at least six major record systems and the requirement for correlating and interpreting these records in conjunction with one another and with other simultaneous information. The total system is geared toward a complete interpretation to the level required in a tactical operation within a period of about two hours commencing with the retrieval of the information whether from the aircraft or from a data link. A detailed breakdown of the signal flow in the reconnaissance center is outlined in Fig. 1-2. The four major operation centers are delineated and the discussion outlines the operations in each area.

1.1.14 Data Correlation Center

One of the confusing aspects of large volumes of information is the requirement to correlate incoming data so that information on the same subject from different sources is properly controlled. Communications coming into the Data Correlation Center will include reconnaissance information provided by strike crews, information from ground forces such as scout reports, patrol reports, simultaneous reconnaissance from naval surface units operating in the task force area, and possibly reconnaissance information from a simultaneously operating reconnaissance sortie. Dealing with the records from the mission which this diagram details, there are two potential sources of information. First, the prime records retrieved from the aircraft itself. These will be "hard copy", processed or unprocessed. They will include imagery from the photographic systems, the infrared system, and the high resolution radar systems, as well as magnetic tapes from the ELINT system, the observer report system, and the key and control system. The second input will come from the second generation of records which are those records relayed over a data link. Once again we will be potentially dealing with photo image, infrared image, high resolution radar

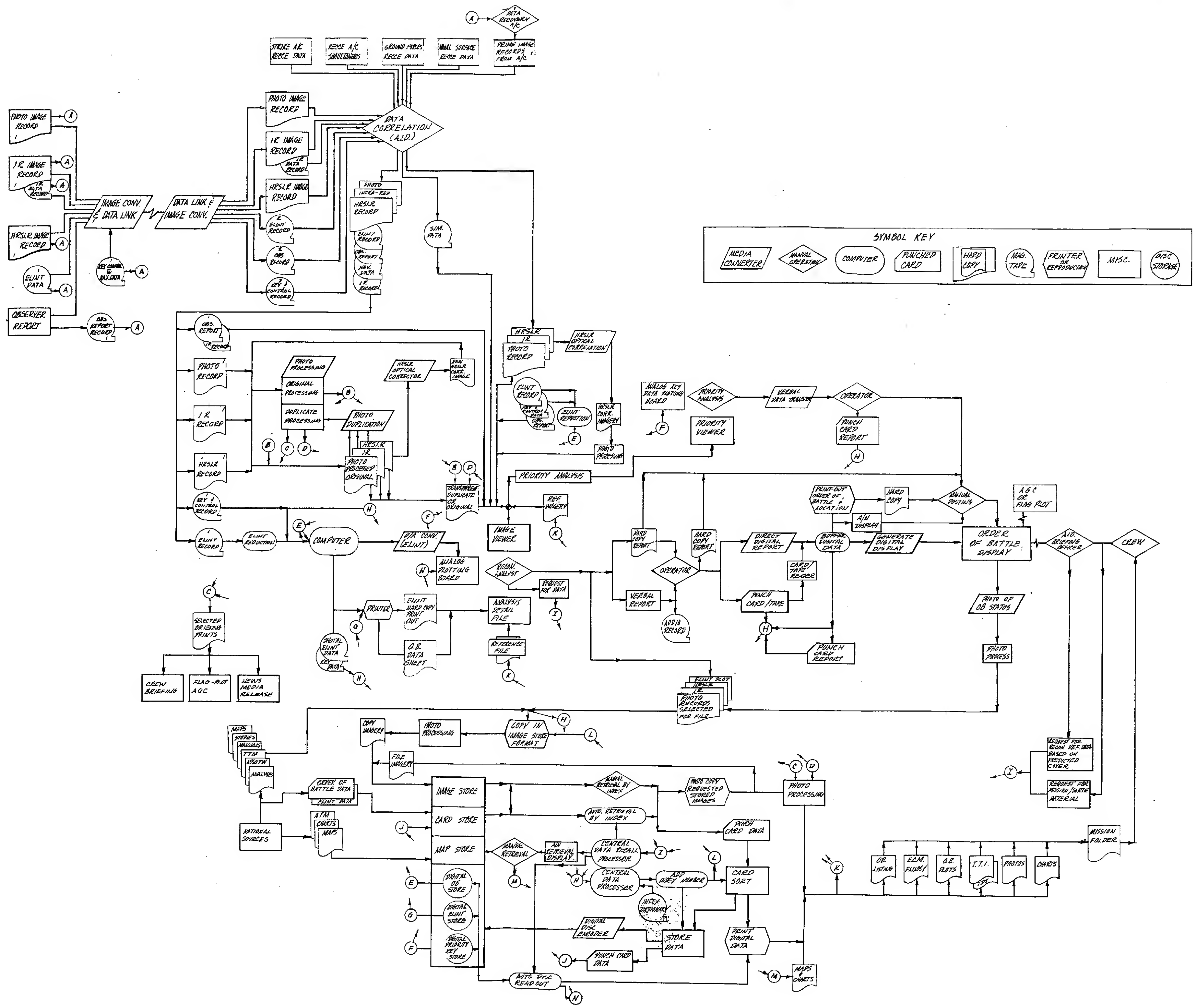


Figure 1-2 — Detailed breakdown of signal flow in the reconnaissance center.

image, ELINT tapes, observer report tapes, and key and control tapes. It is assumed that the data link reception system involves image conversion for those systems which are transmitting images, so that hard copy positive transparency of a photo, infrared, and side looking radar will be available. It is the function of the Air Intelligence Officer to properly direct information coming to him for the best use of the records. His requirement is to provide timely information to the Order of Battle display system which is used by the decision making groups. The Air Intelligence Officer in the Data Correlation Center will relay all of the prime records to the Data Storage Processing and Retrieval area, where those images which are still unprocessed will be handled, and those records which are required in the Data Display and Interpretation Center will be properly set up for use by the reconnaissance analyst. The second generation records on the other hand will be processed directly to the Priority Analysis Center as positive imagery and tape records. The data correlation group will be responsible for properly cataloging and distributing the simultaneous reconnaissance information from ground forces, naval surface units, and simultaneous operations to the Priority Analysis Center or the Data Storage Processing and Retrieval Center (DSPRC).

1.1.15 The Priority Analysis Center (PAC)

The prime requisites regarding multisensor information is that the interpreted results be available as rapidly as possible for command and control decisions by its proper posting on the Order of Battle displays. For this purpose, the positive transparencies of the photographs, infrared images, and side looking radar will be fed directly to the priority analyst who will have an optical priority viewer which will accept simultaneously the 3 to 5 transparency records. He will also have an analog plotting board to display the key and control data information and the flight path of the aircraft. The priority viewer will have an area map on which the location of the aircraft is indicated for comparison with the plotting board. Location of the aircraft will be generated by the automatic reading of the data blocks on the records, or a system using the key and control tape as a major locating system. The priority analyst will take a first look at the records, picking out as rapidly as possible those items of high interest. He may make his report orally and transfer it thus to an

operator associated with him. The operator will prepare a punched card report and simultaneously transfer the information for posting on the Order of Battle board. The punched card report will be sent to the Central Data Processing Computer for disk storage as a priority analysis. As is shown in the diagram, the second generation records may require data reduction. High resolution radar, for instance may require optical correlation and photo processing which is outlined in the diagram. As illustrated in the diagram, the second generation records may be fed directly to the image viewer of the reconnaissance analyst in the DDIC. There is no reason to expect that these records do not contain enough information for some detailed analysis, and indeed if the aircraft has failed to return, the information contained in the data link transmitted reports will be all of the information available on the mission. Since the priority viewer is not intended for detailed interpretation, a flow path is also set up so that the second generation records will be acceptable and compatible with the image viewer in the DDIC.

1.1.16 Data Storage, Processing and Retrieval Center (DSPRC)

In the context of modern multisensor technology, the Data Storage Processing and Retrieval Center is a complex system consisting of computers, photographic processing systems, digital/analog converters, specialized retrieval systems, disc storage and card files, hard copy map stores, and various types of reference and library materials. Into this complex system the prime records of a multisensor mission will be fed from the Data Correlation Center (DCC). For those unprocessed image records, the photographic processing system is used in which the photo IR, and high resolution radar records may be processed. Coming out of the photo processing group the records can be duplicated to provide positive transparencies. In the case of the high resolution radar, an optical correlation step may be required, in which case raw information is cycled back to the original processing group ending up with a transparency which may be a duplicate or an original. The originals of the image records may then be directly sent to the image viewer in the Data Display and Interpretation Center. The viewer can be supplied with either a positive or negative transparency from this processing step. In addition the duplicate processing system can provide prints which will then be available for crew briefings, flag plot perusual and news media releases.

Approved For Release 2009/12/10 : CIA-RDP67B00657R000300200001-5

The observer reports, key and control tapes, and infrared records which are on magnetic tape are processed as required.

ELINT data may require a computer step and an additional analog converter, but the key and control tape will be fed directly to the central data processor and from there to a digital priority key store on a disc recorder. ELINT data will pass from the computer processing step into the digital ELINT desk store. The original infrared tape will be fed directly into the image viewer where a separate retrieval system will be used when the information on the tape is required.

In continuing the discussion of the Data Storage Processing and Retrieval Center, we will at this point note that the original transparency or duplicate positive image has been processed and is available at the image viewer in the Data Display and Interpretation Center. In tracing the data flow it is now necessary to deal with one record at a time. The photo record will be handled as follows. It will be seen that during analysis at the image viewer, the reconnaissance analyst will select photo records for filing. This will include only a small portion of the originals, and those photo records will be processed as shown. They will be copied in image store format, and will require a photo processing step at this point. We will now have copy imagery which will go directly into the image store. The image store may be maintained in several ways, first there may be transparency files, and the original negatives filed and stored temporarily as roll negatives. During the copying stage, an index number will be added to the photographs so that they may be easily retrieved. It is suggested that images be stored and filed against their target type and their geographical location and cross filed in this manner so that they may be retrieved against either index. The index will be generated from an index dictionary, associated with the computer. At this point the original material has been called, and the selected images are filed as either positives or reduced positives properly indexed in the file drawers.

The infrared tape and the infrared image will be dealt with next. Infrared tape will go directly to the image viewer where it will be available for use by the analyst only for detailed interpretation. The major infrared record, which will be a positive transparency, will be handled in precisely the same way as the photo imagery preceding it. The infrared imagery will also be stored

against the index numbers. The data block which will appear in each frame on the photo and infrared imagery, will also aid in its retrieval.

Selected high resolution radar records will be processed through the copy system and stored in the image store format in the same manner as the infrared and photographic imagery. Index numbers will be added and the cross reference system will be used.

Magnetic tape records will require a somewhat different storage system. Among the tape records associated with a mission will be the infrared record, which is a very high resolution analog record of the infrared scanning which has produced the IR image. The tape will be used directly at the image viewer for interpretation of detail and should be maintained as the mission record until all of the mission analysis has been performed. Temporary storage for the IR tape should be provided until the need has passed, at which time the tape should be erased for reuse.

The key and control record tape will have several channels, each of which will contain high density information. This tape will contain a record of the keys which have been produced by automatic thresholding from the sensors. It will contain the navigation information, geographic location, time and other parameters necessary for making an analog plot of the mission and locating the keyed targets. The key and control tape may now become the controlling record for the analyst, in that it pinpoints those locations which require a first look. The tape can be used directly in the image viewer, processed via computer, or utilized in an analog Order of Battle plot board associated with the viewing station. Before being placed in the image viewer, the key and control record can be read into the central data processor which will add the index system. The information on the key tape can then be stored on a disc system so that it can be retrieved rapidly. A first readout of that disc will provide an analog plotting of the keys against the mission profile. The analog plotting board will also contain the last known order of battle symbology, so that new information can be readily distinguished from old. The central data processor, in adding index numbers to the key tape, will also generate a punch card record to be used as backup in the event that the disc storage system is disrupted.

Returning now to the original ELINT tape, the data reduction provided in the computer will be performed and an analog conversion of the ELINT information will be fed directly to the analog plotting board in the analysis center. From the ELINT computer, digital information will be processed through the central data processor into the digital ELINT store which could be a disc store; simultaneously generating a punch card which will remain as the backup system.

The computer associated with the digital analog converter and analog plotting board in the Data Analysis and Interpretation Center will also be used to read a digital Order of Battle disc storage from the main storage system, and convert to the analog plotting board, the location of the currently known Order of Battle symbols. The computer can be connected to a printing device which will provide an ELINT hard copy printout in alphanumeric form and/or an Order of Battle data sheet in alphanumeric form should it be required. Hard copy printout could be added to the detail file for the reconnaissance analyst for reference to a given mission.

The storage and retrieval system which will now be discussed is truly a separate area from the processing and manipulation areas. Coming into the image store section will be information from many different parts of the system. To begin with, this is a depository for all the information from national sources, all charts, maps, target studies, manuals, and reference documents of all kinds can be miniaturized or kept in full sized documents in this area. This area forms the library for the entire reconnaissance section, and contains all of the information from sources outside of the task force. It has previously been stated that selected imagery from a mission analysis will be copied into a storage format and placed in the files. This method of filing is but one of many. Records could be as a transparent file card, information could be reduced to Mitran size, it could also be filed as an aperture card in a punch card system. It has been suggested that information coming into the image store area be processed through a Central Data Processor which has access to the index dictionary, and that index numbers will be added to the information coming in so that it can be cross-referenced by target type or geographical location.

The existence of storage imagery does not delete the requirement for temporary storage of the primary mission records. Primary records should be

maintained until all detailed interpretation has been completed at which time they may be transferred to a national agency, or destroyed to prevent confusion with new records. For this reason, the quality of the copy image must be high so that information is not lost from the original data.

Dealing now with the problem of retrieving information from the storage system. Two major alternatives, one that the information be retrieved from file drawers manually, or that some kind of automatic retrieval system by index be used. Manual retrieval from storage drawers is better suited to the storage system. Using this method, a specific area of the world can be covered by the backup material from national sources. The updating and disposal of outdated material can perhaps be best done in manual fashion. As an example, an area photo print has been requested from the store and identified by its index number. It is a simple procedure requiring only a few seconds for a librarian to retrieve the necessary image in any one of the forms previously mentioned such as a 70 millimeter transparency or an aperture card, process it, and reproduce it or any specific area as a photographic enlargement. The original imagery will be returned to the file, and the print will be processed and sent to the requestor. It is also possible that some of the Mitran information dealing with reference material which was required as part of the analysis detail file will be required for a given mission. This material will be retrieved from the image store manually, a photo copy made, and information passed directly to the analysis detail file for the analyst. It is equally possible that a transparency of a given area for reference will be needed in which case an image can be retrieved from the store manually, a copy transparency made, and processed directly into a format suitable for use in the image viewer. It is also possible that a request for mission or sortie material will be originated by the Air Intelligence Officer for the purpose of briefing strike or reconnaissance crews. This information requested from an image store will be processed in precisely the same manner, that is, the original image will be manually retrieved from the file, the necessary photo copies made, and passed into the mission folder for use by the Air Intelligence Officer for briefings. In this way the newest of material and the newest image cover on a given area can be maintained in the file, even though the material is currently under analysis in the analysis center. It should be noted that a number of the operations which are outlined in the flow

diagram will be simultaneous rather than serial. That is, original imagery can go directly into the image store as soon as possible, even while duplicates of that imagery are being used in the image viewers under active analysis.

In the interest of simplicity, it is just as possible to use the file imagery or the original imagery directly at viewing equipment. This accepts some risk in handling, and means that the viewing equipment must accept imagery in many forms, somewhat complicating that system.

Concerning the problem of punch card storage, alternatives for the retrieval of the cards from the file are either by automatic or manual means. The automatic retrieval system is easier because of the high speed sorting machinery. It is reasonable to assume that the backup store of information will be maintained on punch cards, which can then be used to produce digital or alphanumeric printouts, and for rework of digital disc storage systems. The cards will be generated by the Central Data Processing System which will add the necessary index information to cards coming from the priority and reconnaissance analyst.

It is very difficult for chart storage to be anything other than hard copy material provided long before the mission. Photographic reproduction of these charts is not likely. They will be maintained as hard copy originating in the national sources. Records from the map store will probably be retrieved manually, but could be retrieved after an alphanumeric retrieval display from the Central Data Recall Processor, on request of an analyst or an Air Intelligence Officer for briefings, or any one of a number of other requestors.

Information which is used often, such as digital Order of Battle data, digital ELINT material, and digital priority and key data should be recorded on some system where access is rapid and changes are easy and practical. A digital disc storage system and readout would be the best available for this purpose. Search time for information stored on a disc is quite short and the disc storage system can be changed incrementally without destroying the information on the rest of the disc. In this way the central data processor could process new Order of Battle data directly into the storage disc by index number and location, target type, or any other convenient system. ELINT information stored for the purpose of generating ECM outputs could be conveniently handled in a similar system. The third category of material, would be the key and control

data generated by the priority key system on the aircraft. Maintaining information on digital discs would provide rapid digital/analog conversion and plotting for the priority or reconnaissance analyst. Disc systems have automatic readout, which will help in the retrieval of this high usage material. The disc output can be converted to digital printout, and used in preparing mission folder material, current Order of Battle lists, ELINT, and ECM reports.

In summation, it can be said that the Data Storage Processing and Retrieval Center, is an area where original materials can be photo processed, magnetic tape records can be computer reduced as required, digital information can be converted to analog or other required forms, and the output of these systems can be stored in convenient miniaturized form, or in punch cards. In addition, all of the information can be retrieved in a minimum of time by the use of automatic processing machinery and computers. In this area the library function will be performed and maintained by librarians who will search and reproduce records on request, from any one of several sources. Requests for information will come from the Priority Analysis Center, the Data Storage Processing and Retrieval Center, and the Air Intelligence Officer, for the purpose of briefing strike and reconnaissance crews.

Inputs to this area may come from the analysis group, the priority analysis group as products for file, and from the Data Correlation Center as products to be processed, filed, and simultaneously delivered to the analysis groups. The library function will involve the preparation of all materials to be used in mission folders and briefing folders for air crewmen. The complex part of handling the tremendous volume of multisensor data will fall within this area. Even though the system can be operated manually in any of its phases, the computer aided system allows for the time compression of the tremendous volume of data which is required in order to provide a mission analysis in a reasonable period of time.

1.1.17 Data Display and Interpretation Center

The heart of the reconnaissance center in a multisensor system would be the Data Display and Interpretation Center. This is the part of the multisensor reconnaissance system where the experienced Intelligence Officer interfaces with

the visual, infrared, and radar images and interprets them. The major problem in this area is the proper presentation of the recorded data to the analyst in such a form and with such flexibility that he can, with the shortest possible time delay, determine the location, and character of the targets presented to him. The data flow which is necessary to provide the reconnaissance analyst with the materials and views of the object that he requires, are shown in the flow diagram as the three major blocks surrounding the reconnaissance analyst himself. The major equipment used, of course, is the image viewer which is utilized to present, comparatively, the imagery from the photographs, the infrared, the high resolution side looking radar, and the alphanumeric information from the digital data blocks contained on each of these records. The image viewer, by reading the data blocks, can locate the position of the aircraft, determine when the photograph or record was taken, and indicate the position on an outline map of the area under study. The image viewer should have the capability of use by two analysts, since it will be necessary in some cases to compare the views from more than one sensor at a time. For example, there are a minimum of six potential active records which must be available. They are as follows: first the prime vertical record, which may be from a frame camera or strip camera; second, the forward oblique record, which will be from a frame or panoramic camera; third, the side oblique or panoramic coverage which covers the wide side view; fourth, the infrared image; fifth, the high resolution side looking radar; and sixth, the high resolution panoramic coverage used particularly in high altitude work. There also exists the necessity for having available historical image records which may match in number the new cover imagery. It should be possible to present the historical imagery in a reduced format by miniaturization in the data processing and retrieval group. This multiplicity would seem to make the image viewer an extremely complicated piece of equipment. This, however, is the heart of the analysis problem, and a viewing system which will enable the analyst to select at will those supplementary records which he wishes to use in conjunction with the prime photographic record, is the major problem in the analysis section.

One of the conjunctive pieces of equipment which helps the reconnaissance analyst to determine what he must look at first, is an analog plotting board. ELINT system readouts are reduced to analog plots for use on the display system.

In addition the last Order of Battle status symbology should be recorded on the digital Order of Battle store and reproduced in an analog form on the plotting board, so that a comparison can be made between items already located, and items which are new and demand attention. The supplementary information coming from key records generated on the aircraft will add a third major display component to the analog plotting board. Now to combine with these the representation of the flight path of the aircraft as computed from the navigational information, with pertinent time checks indicated at intervals along that flight path. This overall view of what has transpired during the mission gives the reconnaissance analyst the opportunity of selecting his area for first search on the basis of high density information presented by the key information on the analog plotting board.

The concept of delineating an area of particular interest on the basis of a quick look at a plotting board reinforces another simple procedure. The Air Intelligence Officer will assign a list of 2 to 20 specific targets to a sortie, and a logical reduction in time can be achieved by looking at the area assigned as a target. The combination of assignment and the readout of the key data could be a powerful tool in cutting interpretation time in a critical analysis.

The third interface with the reconnaissance analyst is the detail file of reference material which he has access to at the Data Storage and Retrieval Center. A detailed description of particular targets from generally known geographical locations should be available on file. A detailed analysis of what the assigned targets will enable the analyst to call up the records covering the flight path assigned to the sortie. This information should be precompiled before the analysis begins, and the analyst should be given an opportunity to have looked at comparative last cover on those targets which were particularly assigned to the reconnaissance mission. This reference may be in the form of machine readable punch cards, hard copy readouts from digital analog printing systems, or hard copy transparencies and prints from the image store as called out by the proposed mission plan. The function of the reconnaissance analyst in the Data Display and Interpretation Center is to discover, using the tools given him, what the character and location of the objects of interest are in terms of the Order of Battle status board which he must update. The analyst

must be prepared to form a detailed analysis on any target of particular attention further called out by the Air Intelligence Officer, at the request of decision making personnel. In this regard he must have the ability of requesting new data or supplementary data from the retrieval system. Because the reconnaissance analyst has a difficult task, his interface with the rest of the system as far as reporting is concerned is important. He can generate a hard copy report, that is to say that he can punch out on a keyboard or write out a report of the objects he has seen, their location and the information necessary for plotting this on an Order of Battle display system. Alternatively, however, can give a verbal report to an operator associated with him or with the pair of analysts operating a given viewer. In the case of the verbal report, an audio record should be kept and the operator in turn can generate any hard copy or digital reports necessary. This relieves the analyst of the problem of shifting his attention from the objects before him to a task of manually transferring information in a different format.

The operator's function should not be confused with the analyst's function. The operator's function is simply to relay the information from the analyst to the reporting system. He can prepare hard copy reports in proper format, or he can generate a digital report directly, or a punch card or tape. From the punch card or tape the report will be processed through a digital data buffer and then to a variety of potential flow paths. From the buffer a digital display could be generated directly on the Order of Battle status board. Or, an analog alphanumeric display could be made which would allow manual posting on the Order of Battle status board. We could also printout in hard copy an Order of Battle and location which would then go for manual posting.

The punch card report generated by the operator would be forwarded directly to the Central Data Processor for file in the general library store. Before filing, it would be encoded so that the new information on Order of Battle would be entered in the digital store contained in the disc file.

We now must turn to the problem of dealing with the records which were turned into the reconnaissance analyst for use in the image viewer, and to the reports that he has generated. The analyst can as he progresses with his work, select which of the records are proper to be filed as special information.

He can then order the transmittal of those records directly to the Data Storage and Retrieval Center. They may be copied in image store format and turned into the storage system as image file. The original transparencies used in the image viewer, or the original negative which was manufactured or processed in the Data Storage and Retrieval Center earlier in the operation, should be maintained as a mission record for at least 24 hours or until another mission is flown over the area covered by those records.

In addition to the high resolution radar, infrared image and photo records selected for file, new information should be generated periodically which contains an Order of Battle status board as it appears. A possible way of accomplishing this is to photograph the Order of Battle display board at intervals. The photograph of the Order of Battle status will provide the background information for several supplementary systems. It becomes part of the image store and is a major piece of reference material. A properly processed photograph of the Order of Battle status board could be used as part of the observers display system in the aircraft for the next sortie. The photograph of the Order of Battle status could be used as a data base against which new displays in the aircraft are presented, using a moving indicator to locate the aircraft and present a small section of that photograph to the observer. Overlaying the new symbols so that direct comparison with material already identified can be made immediately by the operator in the aircraft is a possible technique. Thus, the photograph of the Order of Battle status becomes part of the mission material for succeeding reconnaissance missions.

1.1.18 Order of Battle Display System

The end result of the collection of the information in the multisensor aircraft and its processing through the myriad of steps which have been very generally described, is the placing of symbols on the Order of Battle display board. The Order of Battle display is a chart-like representation of a large battle area, with the appropriate symbols which indicate the character, type, and number of targets which have been identified by the interpreters in the Data Display and Interpretation Center. The symbols which are used on this display system are standard and are not within the scope of this discussion. The display system is used to present information to those who are faced with the

problem of making decisions using the reconnaissance information as their base. Information will be, of course, forwarded to flag plot whether that be on the carrier or another vessel, and the information displayed there is also actively used by the Air Intelligence Officer in his function as Briefing Officer for the aircrews whether they be for strike sorties or reconnaissance sorties.

1.1.19 Air Intelligence Officer

As previously mentioned the Air Intelligence Officer will be able to request reconnaissance reference material based on the proposed mission flight plan of each reconnaissance mission. This information will be the general basis on which the reference file will be assembled for use by the reconnaissance analyst. The Air Intelligence Officer will also be requesting mission material, Order of Battle listings, ECM flimsies, Order of Battle plots, photographs, maps, charts, and other pertinent information will go into individual folders for aircrews. The material will come through requests processed by the Central Data Recall Processor in the Data Storage and Retrieval Center.

In this section of the discussion of the data flow through the ground handling equipment we have described generally, the procedures which are possible in handling material of this kind. The flow lines which are on the system diagram will indicate more completely the routes of individual pieces of data and with the general background given by this narrative, a detailed analysis of the system diagram will hopefully be somewhat easier. The purpose of this document is to describe insofar as possible, the functions which attend the collection, interpretation, and display of the information recorded by reconnaissance aircraft using multisensors.

SPECIAL HANDLING

SPECIAL HANDLING

2. VISUAL RECONNAISSANCE

The ability of a pilot or observer to perform visual reconnaissance is limited by speed in a high performance aircraft, particularly at low altitudes. With increasing altitude the ability of a human to resolve needed target information is limited by distance; however, no multisensor aircraft should be configured without allowing some manner of real time report for those targets on which visual reconnaissance can be performed.

The pilots role in visual reconnaissance in a high performance aircraft is strictly limited by the complexity of aircraft operation. In a single place aircraft the pilot will be almost exclusively occupied with problems of operation, navigation and survival. The addition of an observer to a reconnaissance crew greatly enhances the ability to perform visual reconnaissance. Under normal circumstances the observer is not totally occupied with other tasks, and can perform visual reconnaissance at low levels. This is an extremely difficult thing to do because of the rapid movement of the terrain with reference to the aircraft. Any visual observations which will be meaningful would have to be made in the forward direction since the motion component in that direction is minimized. The value of any observations to the side would be doubtful. With increasing altitude the observer would have the ability to look more to the side and perhaps provide valuable information on fleeting targets.

2.1 REAL TIME RECORDS (Fig. 2-1)

A system should be provided so that the observer or the pilot will be able to relay in real time their reports on objects sighted which may be of interest to the analyst. This report could be in clear text, voice radio transmission,

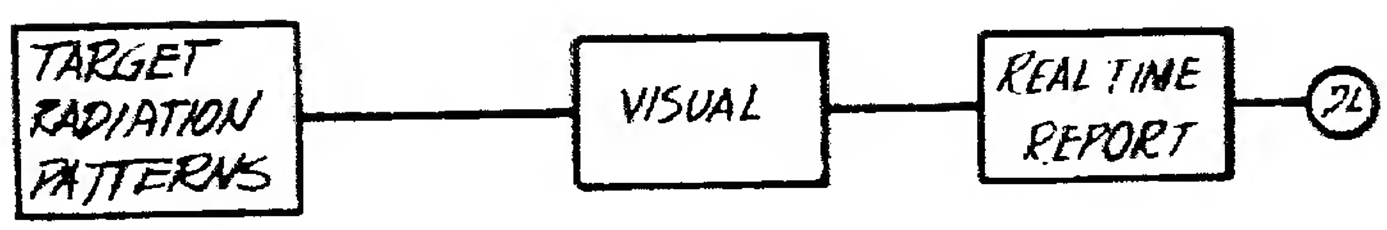


Fig. 2-1 — Visual flow.

SPECIAL HANDLING

Approved For Release 2009/12/10 : CIA-RDP67B00657R000300200001-5

or they could use a digital relay system to transmit the information over a similar data link for priority analysis, where the observation could be analyzed in the context of other new data. Analysis of the information by the observer or pilot is not wise due to the lack of corroborating information and adequate time under most circumstances. In any case, the priority analyst at the data reduction center will be in a better position to use the real time report and take action upon it.

3. PHOTOGRAPHIC SENSOR SYSTEMS

3.1 INTRODUCTION

Normally, the aerial photograph will be considered the primary record against which comparisons of the other sensors will be made. One of the major reasons for using the photograph as the prime record is the ability of the interpreter to relate recognized photographic detail with what he knows in fact to exist. It is possible that in the future some record such as the infrared, might become the prime record. This is not likely until the interpreter is at home with the infrared record and is able to relate it to his own background knowledge and experience. Figure 3-1 is a block diagram of a typical airborne photographic sensor system.

In considering the photographic processes for gathering reconnaissance data, there are several sensor combinations of interest which may provide enough additional information to the analyst to be useful. No attempt is being made to determine whether or not the following systems are providing redundant data, and no consideration is being given to the availability of space, weight, and power in these general philosophical discussions. By and large, the usefulness of the black and white image to the reconnaissance analyst comes because of his long familiarity with colored objects as seen in black and white. It is nearly impossible for the analyst to determine what color exists in an object from a black and white photograph. He has only his understanding of tone and the normal representation of color as seen in black and white. There is no doubt that if real color could be attained with the same resolution and at no additional complication in the system, the analyst might conceivably benefit by having color photography available. The normal sensor systems used in gathering photographic images are not limited to black and white. They can easily accept color

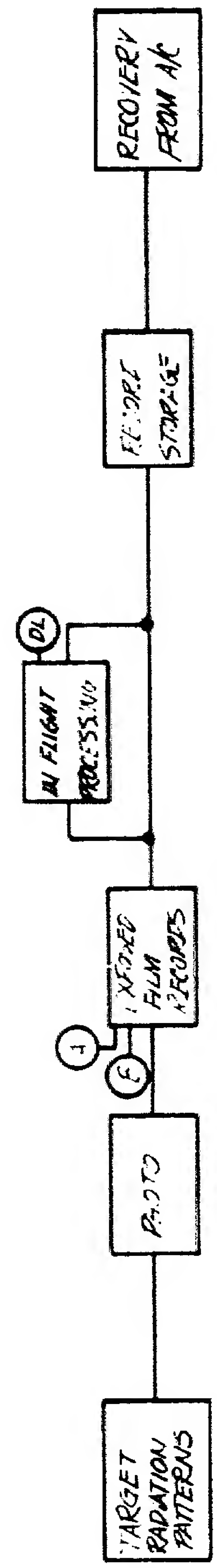


Fig. 3-1 — Airborne photographic sensor system.

images and expose color film. Quite frequently the atmosphere which intervenes between the scene and the camera absorbs some of the wavelengths so that excessively blue/green scenes are produced. This causes lack of true color, lower resolution, and makes interpretation more difficult for the analyst. For this and other reasons, color photography has not been used widely in reconnaissance. Other major reasons include lack of exposure latitude and processing difficulty. Color film emulsions which are multilayered can be sensitized in spectral ranges other than the visual. In particular, a color film, including an infrared sensitized layer when processed, results in a striking visual color representation of information in the infrared range. Film of this type is commonly called color camouflage detection film, and it produces an image which strikingly indicates areas of dead foliage or artificial material in a natural surrounding, thus making it extremely easy to identify camouflage areas. Camouflage detection film of all color materials is the most useful to the reconnaissance analyst.

Color images can be formed using only two spectral bands rather than the three conventionally used in normal color films. One potential system utilizing this method takes two or more simultaneous black and white photographs through properly selected spectral filters. The recombination, after processing, with properly selected color projections provide a reconstituted color photograph which is probably superior in resolution, color balance and ease of processing to tripock color film. It is equally possible to take photographs in the spectral bands including the near visual infrared, and on reconstitution, providing either real color or camouflage detection color representations in which items of interest are strikingly indicated. It would be possible by mounting and simultaneously exposing images in three simple frame cameras to provide a record group which can form a reconstituted color photograph and/or stereo of the same scene. This requires tripulation in all operations and the attendant problems of processing storage, recovery, and correlating the images and properly aligning them for reproduction and/or viewing. However, it should be noted that the very commonly used Technicolor system for motion pictures is precisely this system, that is, color separation negatives are taken on high resolution black and white film, separately processed and then superimposed after processing with the

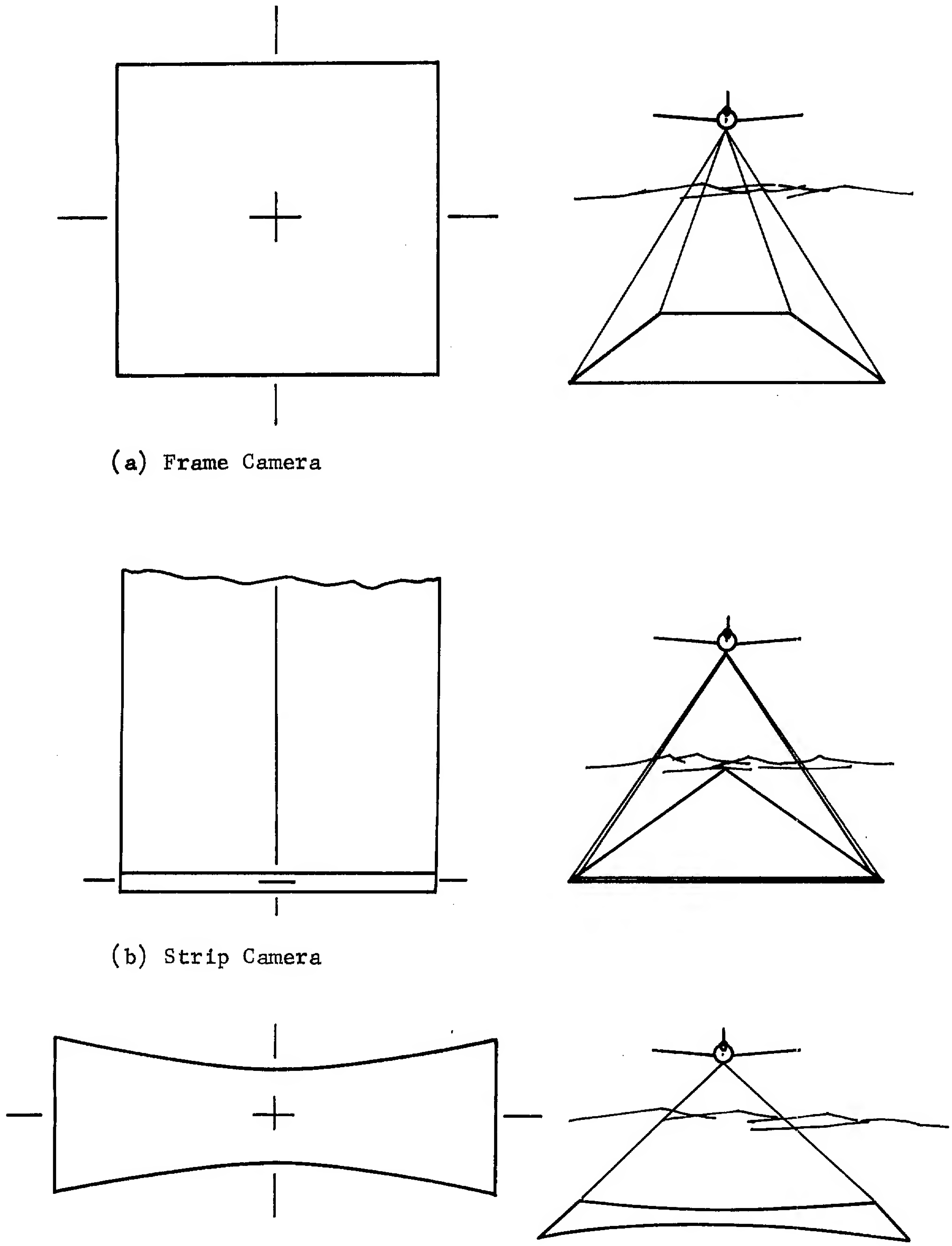
insertion of proper dyes in black and white image. It should be indicated that a great deal of information may be extracted from the sensor system by using redundant photographs and spectral filtering. This information may be useful only for detailed examination and interpretation of a particular area, but it is possible to use it for quick look reconnaissance in the camouflage detection mode. No effort has been made in discussing the photographic process to include all of the permutations which are inherent in a multispectral type of photography. They are simply recorded here for their interest and the philosophical contemplation of their benefits.

3.1.1 Cameras

There are a great number of aerial cameras which are used currently in photographic reconnaissance. They fall into three basic configurations. First is the frame camera, which takes a record similar to a conventional photograph, one frame at a time. Second is the strip camera, which takes a continuous photograph without stopping for frame movement. A typical strip camera will take a frame which may be many feet long. The third major type of camera is the panoramic camera which takes a narrow strip running from horizon to horizon and perpendicular to aircraft track. Figure 3-2 illustrates the typical ground coverage obtained from the three types of cameras.

3.1.2 Frame Camera

The conventional frame camera utilizes a stationary film with a shutter inserted between the film and the lens which provides a high resolution image in the focal plane. Aerial cameras have added a feature to the normal frame camera, in that they normally have provision for moving the film during the exposure to compensate for aircraft movement with respect to a stationary target. The frame camera is used in several positions in the aircraft to provide varying information. Without referring to the focal length of the lens which varies, depending on altitude and required ground resolution, it can be said that the frame camera is used in the following modes. First, the vertical, in which a photograph is taken pointing directly downward to nadir of the aircraft. Second, the split vertical in which two cameras are pointed vertically downward but slightly to the side so that the view overlaps along the center line providing



(a) Frame Camera

(b) Strip Camera

(c) Panoramic Camera

Fig. 3-2 — Typical ground coverage.

a degree of stereo and wider ground coverage. Third, the forward oblique position, in which the frame camera would take photographs of the terrain ahead of the aircraft, with its optical axis pointing forward and somewhat below the horizon. This view is particularly useful from the point of view of adding perspective and penetrating concealed areas. The frame camera is also used in a position pointing to the side of the aircraft to give side oblique coverage. The side oblique photograph is used particularly in combination with the vertical to provide horizon to horizon coverage. Special use of this side oblique is in beach or road running and similar maneuvers where the perspective view is useful to the interpreter. The combination of the two side oblique cameras and the vertical are quite frequently referred to as the tri-camera or fan camera array. By making a mosaic of the right and left side obliques and the vertical, the final laid out photograph covers much the same territory as is obtained with a single frame from a panoramic camera. The frame camera can also produce stereo views by allowing more than 50 percent overlap along the flight path.

3.1.3 Strip Camera

The strip camera is a modification of the frame camera which has a similar lens, shutter, and film format configuration. The major difference is that rather than a shutter, the strip camera has a narrow slit. The exposure is made by moving the film past the slit which coincides with the optical axis, and at a speed which is equivalent to the image motion produced by the moving aircraft. The strip camera is used on low level missions, especially where a continuous record of the scene below is desired, or where the problems of film movement and shutter cycling are excessive. The strip camera generates, on a film, a continuous image of the landscape passing below the aircraft. It is primarily used in a stabilized vertical position because of the complications which arise when the format is tilted with relation to the ground below. These complications come from the difference in image motion speed from one edge of the format to the other. Similarly, the strip camera is difficult to use in the oblique position because of the continuous change in image motion across the format. It is not possible to provide stereo photography with a strip camera unless two records are made at varying forward and aft angles of view. The problem of ground coverage with a strip camera can sometimes be dealt with by using wide angle

short focal length lenses, which are able to photograph areas with up to 120 degrees scan angle. It is possible to conceive of a camera with a compound shutter which is able to operate both in a frame and strip mode. This could be accomplished by using the strip camera film movement to provide image motion compensation in the frame mode.

3.1.4 Panoramic Cameras

The third major category of photographic equipment for aerial use is the panoramic camera. In this camera, the lens film system is mounted so that a long photographic format is taken perpendicular to the line of flight. With appropriate design, cross-track coverage can be from horizon to horizon. The lens is generally rotated around its nodal point, and a curved film surface is provided so that the image is painted across the stationary film during exposure. There are modifications of this system but basically synchronous motion must be provided between the lens and the film in order to sweep the picture. This camera can be used to provide stereo coverage by overlapping succeeding images along the flight path by at least 50 percent.

The panoramic photograph is distorted because of the difference in scale from the edge to the center of the format. For exacting exploitation, rectification of this image is required. A panoramic camera design is currently available which maintains a constant scale across a format by varying the focal length as the scan angle is changed. A system such as this provides a high resolution wide angle picture. There is no commonality of format or geometric distortion between a panoramic camera and frame or strip cameras in their operational modes.

3.1.5 Miscellaneous Camera Systems

A family of electronically amplified low light level cameras are currently in development. These cameras are reported to operate at light levels approaching 1 to 5 foot lamberts. Much work is in progress on this problem, and results show some promise, in that the very low resolutions are being achieved.

Laser cameras (laser radar) are presently in active development. Limitations in available laser emission energy restrict prototype operation to around

1000 feet of absolute altitude. Image resolution being achieved is extremely coarse.

In tracing the processing of target radiation patterns through the photographic system of a reconnaissance operation, it should be noted that any of the photographic sensors will produce a record consisting of differentially exposed silver halides in a gelatin emulsion coated on a transparent polyester or acetate base. The exposed film record is of great interest to the reconnaissance analyst, and it is this record which he will eventually have to deal with in one form or another. The latent image on the exposed emulsion must be protected from stray-light and stored in some convenient manner. The exposed film record will be almost always contained on a takeup spool, and found in either a magazine which contains both the supply and takeup or in a separate takeup magazine. Most cameras in addition to the exposed image contain other pertinent information required for intelligence analysis or graphic reduction. For this purpose the data block which contains information on geographic location, height, velocity, compass heading, and a number of other useful statistics is recorded at an appropriate location of the film, depending on format. These cameras may impose on the film margin, or some other appropriate location, markings identifying thresholded or key information generated by other systems in the aircraft. It is possible for example, to impose an identifying key which is digitally coded to indicate when the side looking radar has detected a moving target, when an infrared hot spot has been located, or when an ELINT emitter has been identified and located. A device similar to that used for imposing the data block could easily record a digital word of eighteen or twenty bits which would identify the key information for the interpreter during his analysis.

3.1.6 Inflight Processing

The next step in tracing the radiation pattern through the photographic system involves processing the latent image. One alternative is to inflight process the material so that a finished permanent image is available as soon as the aircraft returns from its mission. There are a number of methods for inflight processing. They involve such techniques as web processing monobaths saturated in a sponge like base and simply sandwiched with the film on a storage spool. Another is an inflight processing system. This involves conventional

three step developing, stop, fix and wash, which can be accelerated by chemical and temperature manipulations. The third possible method involves using a base material saturated in a monobath processing solution which when wrapped with the negative film will form a positive image by diffusion transfer during processing of the negative. Utilizing this method, a positive and a negative record would be available on aircraft recovery.

At this point, assuming that inflight processing has been done, it is possible to convert the visual image to electronic signals and relay the image in real time to a receiving/printout station where analysis could be done on the reconstituted record. There are time data limitations which dictate rather a low level of transmitted information because of transduction and transmission bandwidth problems. Image transmission can be incorporated with the processing unit. These data link readouts are limited in their ability to transmit much greater than 20 lines per millimeter from the original negative. The rate at which they can transmit this information is also limited by the available bandwidth on the data link.

3.1.7 Record Storage

Regardless of the origin of the record and whether it is processed raw or has been passed over the data link or not, the storage requirement still exists. In the case of exposed and unprocessed film, the normal storage on the takeup spool in the magazine is sufficient. In those cases where processing or readout has been done, some auxiliary storage system must be provided which will maintain moisture and temperature, and provide easy access when the aircraft returns from its mission. Where processing has been done, a separate takeup will be required for the processed negative and one for the positive if it has been produced.

The next step in following the system through, involves the recovery of the record from the aircraft. This will normally be done manually and no special analysis of this portion of the procedure should be required.

3.1.8 Photography in the Near Visual Range

There is considerable information which is to be gained from photography especially adapted to the spectrum range which is close to the visual. A special photograph in the ultraviolet or infrared range may provide interesting information to the reconnaissance analyst. Of particular interest in the tactical system is the use of a near visual infrared capability inherent in some photographic emulsions. Any of the sensors mentioned in the photographic section, that is, frame cameras, strip cameras, or panoramic cameras, can be used because the near visual systems require only that the proper emulsion be used in recording the images. Infrared films can detect activity, camouflage, and other interrelations when compared with the visual photographs. Considerable interest has been shown in shallow water obstruction analysis by using infrared photographs in conjunction with visual range photographs. A color photograph, similar to the color camouflage detection films can be obtained by taking the same target in the visual range and in the infrared range and displaying them using color contrast projection systems.

3.1.9 Exposed Film Records

The record from the near visual photographic systems will once again expose latent images in the emulsion of the aerial film. The cameras should impose on these record data blocks containing the geographic location and other pertinent information about the particular exposure parameters. The ability to impose on the margins of these films a record for keys or other system operations is similar to that for the normal photographic systems.

Near visual photographic records are just as easily processed inflight as normal emulsions, and the same alternatives exist in that they may be processed by a web material, by a conventional three solution system, or they may be processed to give a negative and a positive. The positive or the negative could be read out over a data link system involving a line scan or a flying spot scanner exactly as is done with the visual photographic materials.

4. HIGH RESOLUTION SIDE LOOKING RADAR SENSOR SYSTEMS

Unlike photography and infrared, radar is essentially an all weather sensor. The ability of radar to penetrate clouds is a function of the wavelength employed. Radar used for weather surveillance uses short wavelengths (K-band) which will not penetrate dense clouds. Reconnaissance radar uses longer wavelengths, usually X-band, so that weather is penetrated.

Radar is an active sensor. Unlike photography and thermal systems which collect respectively reflected and emitted energy, a radar system directs energy to the ground and processes the reflected signals, so that a map-like representation can be presented. Therefore, the target radiation patterns which have been discussed for the passive imaging systems are not of concern here. Instead, the characteristic radar reflective cross-section is the radiation pattern which will be analyzed.

In conventional radar systems, resolution is achieved by radiating a beam sufficiently narrow so that the width of the beam at the desired range gives the required resolution. Similarly, a conventional radar's range resolution is achieved by radiating a pulse whose width corresponds to the desired range resolution. The result of these conventional techniques is a radar whose range resolution is essentially independent of range, but whose ground resolution deteriorates with range since a constant angular resolution is achieved. In many instances, a short pulse technique is adequate for the achievement of useful range resolutions. However, in many cases the linear azimuth resolution desired cannot be achieved with practical parameter values (antenna size).

4.1 SYNTHETIC RADAR ARRAY

For airborne mapping applications, the length of the antenna which can be carried in an aircraft is limited. For this reason, a means to achieve fine

resolution without the necessity for long physical antennas were sought. The synthetic antenna technique has been successfully used as a solution to this problem. This technique uses linear motion of a significantly smaller antenna, together with signal analysis operations to generate a synthetically long antenna. Analysis of the operation involved shows that a linear azimuth resolution can be achieved which is independent of range and frequency, and which depends only upon the aperture of the physical antenna used.

The reasoning leading to a synthetic antenna is essentially as follows. In a linear array the beamwidth of the array factor is inversely proportional to the length of the linear array, so that one achieves narrower array factors by using longer arrays. In a physical linear array, each of the elements of the array exists physically, and each element transmits and receives signals simultaneously. Signals from the radiating members of the array are combined, so that appropriate vector summation of signals gives the radiated beam pattern associated with the array.

In the synthetic antenna case, however, only a single radiating element is used. This element is moved so that it occupies in turn each of the positions of the linear array. At each of these positions a signal is transmitted and the radar echoes are received. The received signals are put into storage and subsequent processing of this data is used to combine these signals in a manner appropriate to synthesize a long aperture antenna. To do this, the operations must preserve the essential vector character of the signals, so that a coherent radar system preserving both phase and amplitude is required. In the case of synthetic antennas, array lengths of thousands of feet are possible. These antenna lengths are achieved by translating a small antenna to form a synthetic array.

The notion of a synthetic antenna beam first received attention prior to 1953. Since 1953, however, much more intensive activity has been devoted to synthetic antennas. Many systems have been built and flight tested since that time, and flight test results of successful systems are available.

It is evident that since the radar signals are put in storage for forming a synthetic array, there are some degrees of freedom available in the case of a

real physical linear antenna. For example, one can generate a synthetic antenna which is focused at all ranges. An expression for the resolution achievable in the focused case is given in Eq. (1) below,

$$L_{eff} = \frac{\lambda R}{2D} \tag{1}$$

where L_{eff} is the effective synthetic array, antenna length required for a given resolution, λ is the radar wavelength, R is the range to the target, and D is the -4 db resolution of the synthetic array.

The radar system specifications for tactical reconnaissance and surveillance, especially the range and resolution requirements, coupled with typical restraints of weight, volume and reliability duplicate a radar of essentially high performance which can only be achieved by means of synthetic aperture, focused, coherent, side looking radar. The requirements for coherency and signal processing required for the synthetic array fine resolution mapping also make this type of radar valuable for moving target indication (MTI). There can be a choice of these functions or fine resolution mapping and MTI can be performed simultaneously. Operation in the MTI mode can be performed with the radar beam "squinted" 45 degrees forward so as to provide alerting for the mapping radar function and the other sensors.

There are three modes of operation which can be considered for the mapping function for such a radar:

Mode 1 — The radar signal is recorded by an airborne recorder. The recording is delivered upon landing on the carrier to a data processor unit where the radar images will be produced.

Mode 2 — The radar signals may, instead of or in addition to the above, be transmitted in real time via a line of sight wideband telemeter link to the processor unit on the carrier.

Mode 3 — The radar signal will be recorded as in Mode 1, but radar images will then be produced immediately by an airborne processor and displayed to the aircraft crew for the monitoring of radar operation output, for limited data interpretation, or selective graphic transmission.

The technical characteristics of the radar can be broken down into the following categories: data output, resolution and contrast, ambiguities, area coverage, vehicle flight path, vehicle altitude, measurement of aircraft motions for radar signal correction, antennas, squint angle, test equipment, weight, volume, and power requirements.

The synthetic array radar can yield two distinct types of signal output, namely ground radar imagery, and moving target indication (MTI). These two types of output can be processed simultaneously, or can be separate modes of operation. The advantage of simultaneous processing is that the location of moving targets can be directly superimposed upon the radar imagery. The advantage of different modes of operation is that the radar parameters such as PRF, range resolution and range coverage can be optimized for each type of output. In order to make the signal flow description illustrated in Fig. 4-1 more understandable, only simultaneous operation will be assumed. The alterations in signal flow for operation in the other two modes is obvious and simple.

For many interesting ground targets, the closing rates are low enough so that the target doppler shift does not separate the target radar return from the ground clutter spectrum. Processing the returned signal for these slow moving targets necessitates employint monopulse or displaced antenna phase center techniques. The effect on the signal processing is that there are two distinct signals at the output of the SLR (5.1) - (Numbers refer to the numbers of the boxes in Fig. 4-2.) However, by inserting an appropriate delay in the MTI signal data, these two signals can be time multiplexed so that only one output "wire" is required.

The electronic signal (5.2) at the output of the SLR therefore is a time multiplexed signal as shown in Fig. 4-2, consisting of the right side (right side or left side refers to the side of the aircraft on which the ground being observed is located) radar imagery signal, the right side MTI signal, the left side radar imagery signal and the left side MTI signal. This sequence is repeated at the PRF rate. If only one section of the data is required it is easily separated by electronic gating.

There are three categories of signal flow and display to be discussed; these are, 1) permanent record recording and physical recovery of record after

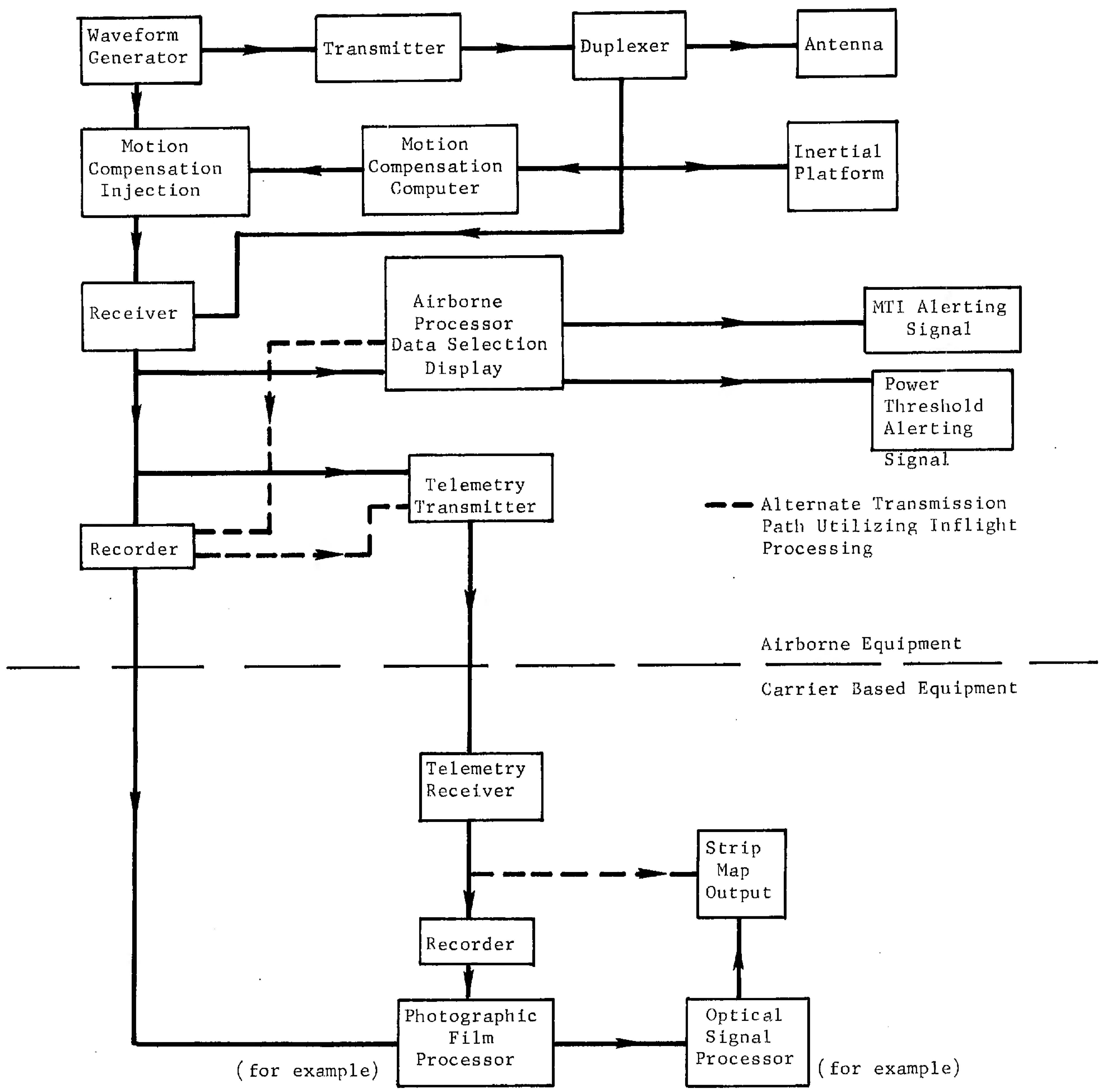


Fig. 4-1 — Functional elements for radar system.

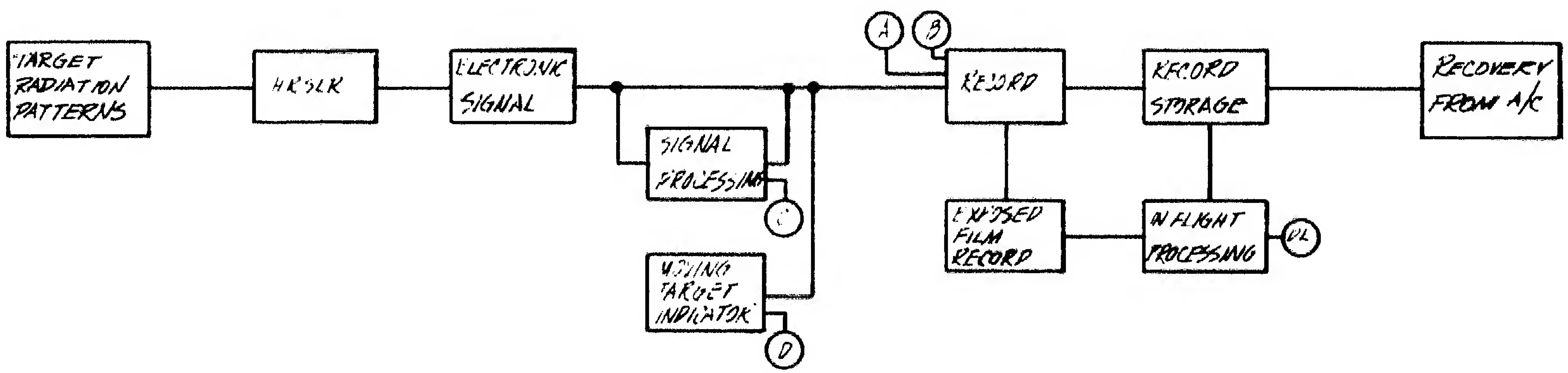


Fig. 4-2 — Airborne high resolution side looking radar sensor system.

aircraft landing; 2) data link transmission; and 3) short time signal processing for aircraft operator display or automatic target indication.

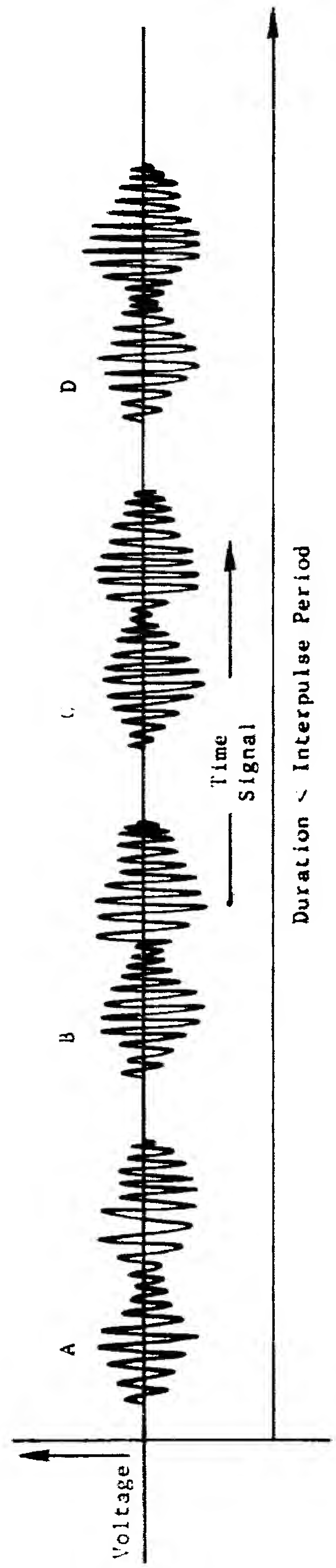
The essential functional elements for the radar system are identified in Fig. 4-3. Microwave energy is generated in the transmitter, passed through the duplexer, and radiated from the antenna toward the selected target area. The returning scattered radiation is passed through the duplexer to the receiver, and then to the recorder or telemeter link subsystem. A signal processor is provided, either as carrier based equipment or as airborne equipment to convert the recorded signals into a focused map image. Inertial motion measuring instrumentation is provided to correct the radar data for irregularities in the motion of the aircraft. Inertial equipment will also provide appropriate inputs for scaling, orienting, and restituting the map images. The antenna is stabilized by use of information from the inertial platform, so that the antenna beam will always point at the appropriate squint angle.

In the selection of the design parameters for the radar to satisfy given mission requirements, tradeoffs must be made along:

1. The attainment of the superior resolution with adequate detection sensitivity for the prescribed operating geometry.
2. The necessity of having the equipment completed, tested, and operating reliably within the prescribed schedule.
3. Integration of the radar into the overall system and compatible with the other sensors.
4. Minimum system cost.
5. The most important of all, providing timely information to be used as the basis for tactical decisions.

4.1.1 Sample Parameters

It is not possible to choose specific system parameters for a radar of a tactical reconnaissance aircraft without first defining the system requirements. However, various tactical reconnaissance fine resolution radar system designs have been considered, and the list of parameters given in Table 4-1 illustrate the principal features of such a radar. These parameters are based upon a



Right Side
A Imagery Signal
B MTI Signal

Left Side
C Imagery Signal
D MTI Signal

Signal is bipolar video. Bandwidth of MTI signal may be less than bandwidth of imagery signal.

Fig. 4-3 — Electronic signal format high resolution SLR.

SPECIAL HANDLING

Approved For Release 2009/12/10 : CIA-RDP67B00657R000300200001-5

Table 4-1. Examples of SLR Parameters
(AN/APQ-108 Derivative)

System			
Aircraft Velocity		Mach 2.2	
Altitude*		40,000 - 60,000 feet	
Maximum Range*		100 nautical miles	
Range Interval Coverage*		10 nautical miles on side, 20 nautical miles total	
Design Resolution		8 feet	
Transmitter			
Radiation Frequency**		X-band	
Average Power		440 watts	
Peak Power		200 kw	
Pulse Expansion Ratio (variable)		300	
Pulse Length (actual)		3 seconds	
Pulse Length (effective)		10 nanoseconds	
Basic PRF (pps)		735	
Antenna			
Physical Length		75 inches	
Physical Height		17 inches	
Receiver			
Bandwidth		100 megacycles	
Noise Temperature		1300°K	
Physical Characteristics	Without Antenna	With Antenna	Without Antenna With 6 nautical mile Coverage
Estimated Volume (cu. ft.)	27	50	17
Estimated Weight (lbs)	920	1000	620

* High altitude mode.

** For general mapping, low frequency option for foliage penetration at short ranges.

design which is a derivative of the AN/APQ-108 radar. This derivative design is intended for use in a high performance aircraft. A program leading to production of this design is feasible with current technology.

In many tactical reconnaissance applications, the total maximum ground coverage is set by the weight and volume that can be allotted to the recorders, and there is a choice between selecting wider coverage on one side of the aircraft at a time or a narrower coverage for both sides simultaneously. There is also a choice between full coverage at gross resolution or fine resolution over a narrow region. Three to four hundred pounds of weight can be saved in recorders, if the coverage is limited.

4.1.2 Configuration Requirements

For fine resolution radar in a tactical aircraft with coverage on both sides of the aircraft, two antennas mounted on opposite sides of the aircraft would be employed. Since the purpose of motion correction is to correct for the phase centers of these antennas, the inertial platform should be placed as nearly as possible between the antenna flexure and will simplify the calculation of the correction term.

The output transmitter tubes and the input RF amplifier (a parametric or tunnel diode amplifier) should be placed as close as possible to the antennas, in order to minimize transmission losses. The location of the remaining radar components is not critical, but the recorder and processor require an environment with low temperatures and a minimum of vibration.

4.2 ELECTRONIC SIGNAL AND SIGNAL PROCESSING

The first of this category represents the type of data handling employed for all operational and most developmental synthetic array radar systems at the present time. The electronic signal is recorded on 70 millimeter or 5 inch photographic film by a cathode-ray tube line scan recorder, which is intensity modulated by the bipolar video signal. Space is left on the film for timing marks, a data block, and priority action flags which are recorded with a small auxiliary CRT.

The exposed film (5.3.1) can be taken up on a spool and left undeveloped in the record store (5.4) until removal on the carrier, or it can be developed by an inflight processing unit (5.3.2). In this latter case, the processed film is then placed in record storage. In either case, the raw signal data rather than the processed image map or MTI output data is stored.

4.2.1 Focused Electronic Processor

Theoretically, the processing of the coherent radar return for a high resolution radar could be performed by a purely passive electronic filter. However, because of the large time bandwidth products involved and the long integration times, an intermediate storage medium is required. In optical processing, this medium can be supplied by photographic film. In electronic processing it may be supplied by delay lines, storage tubes, or other means. Thus far, electronic processing has proved less efficient than the coherent optical processor in terms of the weight and power required for processing at a specified data rate (resolution elements/second). Further developments in storage media and electron beam technology, however, may make electronic processing very attractive in the 1967 era.

The coherent video data from the radar is converted into modulation on the appropriate recording mechanism (for example, light or an electron beam). This data can be read out immediately (after an integration time of data is recorded) or stored, to be processed later. The read transducer scans the recorded data along a constant range contour, and the doppler recording is converted into an electrical signal. Since the doppler frequency of a target is not constant but has a linear or possibly high order sloper, a focusing correction is made by mixing with a linear frequency sine wave or using a dispersive compressive network. The processing for different ranges and for different doppler histories can be done sequentially.

A limitation on electronic processors which have been developed to date, is their inability to perform quadrature component processing thereby aggravating the ambiguity problem. A method of performing two-dimensional quadrature component processing for electronic processing by employing space modulation of either a readout electron beam or light beam has been developed.

Table 4-2 lists some of the possible combinations for an electronic processor. Electron beam recording is preferred, because it can be extended to bandwidths of hundreds of megacycles and fairly fine resolution. However, electron beam readout cannot be performed to the same resolution as a light beam readout, which thus makes the latter more desirable from this standpoint. Therefore, a combination of electron beam write on thermoplastic material and light readout using Schlieren optics, followed by a dispersive line integration device appears to give the maximum performance within the state-of-the-art.

4.2.2 Coherent Optical Processor

High resolution radar systems require the recording of data for a sufficient length of time to generate a synthetic antenna which, in turn, is processed to produce the high resolution strip map. Because of the widespread use of optical processors to convert the high resolution data into a strip map, it has been customary to employ normal photographic film in both the signal recorder and the output processor. Unfortunately, photographic film requires a finite development time, as well as the use of chemicals which are sometimes not acceptable in certain applications. It is therefore desirable in the advanced development of high resolution radar to develop a recording system which provides rapid access to the data for processing with as short a time delay as feasible. This section, therefore, discusses some of the methods that have been proposed to accomplish a greater speed in the processing of high resolution radar data.

The state-of-the-art for presently available recording-processor systems consists primarily of a cathode-ray tube, which converts the electrical signals into intensity variations on the phosphor which are imaged or contact printed onto a photographic film. The photographic film is then developed, either immediately or returned to a ground base which also includes the data processor. For high data rate systems, an automatic developing machine is usually included returning the signal film to the processor for processing in a time which depends essentially upon the length of film recorded. The nearest thing to a real time system is when the development takes place immediately upon production of the signal film. This development would take place in a rapid film processor, and could be done in less than ten seconds with present technology. This also

Table 4-2. Focused Electronic Processor Types

Storage Media	Recording Transducer	Recording Scan Method	Read Transducer	Read Scan Method	Remarks
Photographic	Cathode-Ray Tube	Electron Beam Deflection	Flying Spot Scanner and Photodetector	Electron Beam Deflection	Development Time > 10 seconds
Kalvar Film or Photochromic Film	Cathode-Ray Tube or Laser Modulated by Ultrasonic Cell	Electron Beam Deflection or Mechanical Prism Scan or Ultrasonic Cell Scan	Flying Spot Scanner and Photodetector	Electron Beam Deflection	Very short developing time but sensitivity limits input bandwidth to < 1 mc. Possibly this can be circumvented by use of high power CW laser.
Storage Tube	Electron Beam	Electron Beam Deflection	Electron Beam	Electron Beam Deflection	Limited resolution and coverage (approximately 600 resolution elements across field of view for current tubes).
Electrostatic Tape	Electron Beam	Electron Beam Deflection	Electron Beam	Electron Beam Deflection	Resolution and coverage will be improved by factor of 2 or 4 over storage tube but device is still in R and D phase.
Thermoplastic Tape	Electron Beam	Electron Beam Deflection	Flying Spot Scanner and Photodetector	Electron Beam Deflection or Mechanical Prism Scan of Light Beam	Appears to be most promising technique. Coverage of 5000-10,000 resolution elements in range is possible with reasonable development.

involves the use of various chemicals which must be stored and handled appropriately for various missions. The supply of chemicals also must be replenished periodically.

A second category of signal utilization involves data link transmission to relay signals to the carrier while the aircraft is in flight. Such transmission can involve either the raw signal data or the processed radar imagery and MTI output data. The choice depends upon whether system tradeoffs permit the use of a short time signal processing unit (5.2.1) aboard the aircraft. In any case, the requirement for low altitude, long range missions rule out the exclusive use of real time data transmission, and requires a buffer storage in order to store the reconnaissance data until the geometry of the aircraft carrier is advantageous for transmission. The film recorder (5.3) and inflight processor (5.3.2) can serve the function of this buffer storage. The developed film, either raw data or imagery, can be read out for data transmission by the use of a flying spot scanner (either CRT, optical prism scan or line scan tube) and a photodetector. The timing and data block information can be read out at the same time, to insure proper registry and interpretation of the transmitted data.

4.2.3 Short Time Processing

The third category consists of short time signal processing (5.2.1) and moving target indication (5.2.2) aboard the aircraft for operator display and automatic target indication. In general, inflight short time signal processing, with the present state of the art, compromises resolution or range coverage when composed with that obtainable when recording raw data only. When delay times of 10 to 60 seconds are acceptable, the short time signal processing unit can use the developed raw data records from the inflight processor (5.3.2) for the input signal. If shorter delay times of 0.1 to 10 seconds are required, then another storage medium other than film must be used.

One type of signal processor unit which has been developed is one employing a two-gun electronic storage tube (see description in Volume IV). This type of processor can handle 400 to 600 range elements per tube with present day tube capability. For example, this would give approximately one mile range swath coverage with 15 feet resolution. Further developments with two-gun tape storage tubes may increase this capability by a factor of four.

The same type of processor can handle radar imagery and MTI signal data with minor variations in the output filtering units. Also, imagery and MTI signals can be handled simultaneously as long as the total number of range elements required is kept below the capability of the storage tube. The radar imagery and/or MTI target indication data can be presented to the operator's display for inflight interpretation or it can be recorded on film in the recorder (5.3) for record storage or data link relay after inflight processing. In addition, moving target indication data can be used for automatic target indication and location. It is also possible to indicate "large" radar cross-section targets with the signal processor (5.2.1) output.

The description of the storage and processing methods for synthetic array radar given here assumes film recording and a storage tube processor for short time processing. This is for the purpose of avoiding digression into various choices of techniques which is discussed in Volume IV. This is not meant to preclude the choice of other techniques upon the details of time scale, requirements and weight and volume limitations.

4.3 RECORD

There are available a number of recording techniques which include magnetic tape, CRT writing on film, and direct electron beam writing on film, thermoplastic, and electrostatic recording materials. A recording system utilizing electro-optical techniques can employ cathode-ray tubes with fiber optic face plates, which record on fine resolution photographic film. Present capability of this type of recorder is about 3000 line pairs per 5-inch recording CRT which is equivalent to about 15 feet range resolution over a range interval of 7.5 miles. Wider coverage can be obtained by using multiple recorders although further development of recording techniques will also improve the coverage of each recorder.

After processing, the map is normally in the form of a photographic transparency which must be developed. However, this is not quite as crucial since the output can be read from a vidicon tube, for immediate analysis. Excluding for the moment the development of the film, the cathode-ray tube and film

combination have already been highly developed. However, there are two factors which essentially limit their performance; 1) the amount of energy required to expose very high resolution film is simply not available from the phosphors that are now produced. In order to increase the resolution it is necessary to increase the amount of energy due to the reduced sensitivity of high resolution emulsions; 2) it is also extremely difficult to increase the resolution at the cathode-ray tube retaining the same amount of energy. Systems at the moment utilize approximately 50 lines per millimeter on the photographic film which is also about the limit for the tube face. In order to use a higher resolution film it would be necessary to increase the energy and decrease the spot size greater than is presently available. The limitation to approximately 50 lines per millimeter also requires bulky systems in some instances where large range intervals are to be recorded.

A number of new methods have been proposed to overcome the difficulties of the cathode-ray tube, photographic emulsion interface as discussed in the previous section. These may be briefly tabulated in the following manner:

1. Direct electron beam recording on a material which is then processed.
2. Recording by a cathode-ray tube on a photosensitive material which is very rapidly developed by heat or some other means.
3. Recording with a laser light beam, which is scanned and modulated onto a photosensitive material as in 2.

4.4 TARGET RECOGNITION AND LOCATION

4.4.1 Moving Target Indication

Moving target indication covers many phases including the detection and recognition of moving targets and the determination of coordinates, velocity, and direction. The presence of moving objects is an important clue in the recognition of target complexes and in determining fluid military situations. It is, therefore, desirable to have real time airborne processing for MTI so that it can serve an alerting function and can aid in selecting sensors for limited spot coverage. One can visualize an "ideal" MTI processor for use with a high resolution map display which would superimpose upon the display arrows

indicating the magnitude and direction of the target velocity vector at the correct position. An MTI processor design should come as close to this ideal as possible, with the input data available.

There is a conflict in the optimization of radar parameters for the detection and resolution of both fixed and moving targets. MTI considerations alone would dictate a forward looking radar to minimize doppler spread of the ground return and thus would maximize the number of targets in the clear region. On the other hand, in order to minimize the integration time required for a given resolution for fixed targets, a side looking radar would be used. However, by making use of the displaced phase center technique, it is possible to adequately cancel the clutter, even for a side looking radar and still detect moving targets with velocities much smaller than the maximum velocity spread over the real beam. This MTI technique is compatible with the simultaneous generation of a high resolution map, and the high resolution feature greatly reduces the area of ground clutter with which the moving target competes. It is expected that this type of MTI will be thoroughly proven out by the post 1967 era.

The techniques used for an MTI processor are practically identical to those used for the high resolution radar map processor. In fact, it is entirely feasible to design a processor which is compatible with both of these functions. However, it may prove desirable to have an electronic processor for the MTI function alone. This electronic processor can be used as a relatively gross resolution airborne monitor of the radar mapping performance and can be used for MTI. In this second mode, MTI alerting signals can be generated with azimuth and range position data so that the area of interest can be mapped (by the radar and other sensors) with fine resolution.

For example, the parameters for an alerting MTI radar system can be:

Squint angle = 45°
Range resolution = 100 ft
Azimuth resolution of clutter path = 100 ft
Range measurement accuracy = 100 ft

The azimuth placement accuracy of a moving target depends upon the radial velocity uncertainty, which for vehicles averages around 30 fps and for men 3 fps.

That is:

$$\Delta\ \theta = \frac{\Delta\ V}{V\ \cos\ xy}$$

where

$\Delta\ \theta$ = angular uncertainty

$\Delta\ V$ = velocity uncertainty

V = velocity of aircraft

γ = squint angle

for $\Delta\ V$ = 30 fps and $x = 45°$

$\Delta\ \theta$ = 0.014 radians for V = 3000 fps

and $\Delta\ \Delta\ \theta$ = 0.035 radians for V = 1200 fps

The maximum angular uncertainty, however, will never be larger than the beamwidth of the physical antenna and, by complex data processing can be held to a tenth of this beamwidth even for large velocity uncertainties.

The alerting time, defined, as the time between MTI detection and the crossing of the target in the broadside direction is given by:

$$t_a = \frac{R_{\cos}\ \gamma}{V} \quad (3)$$

For R = 50 n.miles, γ = 45°

V = 3000 fps, t_a = 143 seconds

The limit on clutter cancellation ratio for the displaced phase center technique is set by equipment limitations and, based upon the perforance of present cancellation techniques, is estimated to be approximately -30 db. Unfortunately, part of the return for slow moving targets is also cancelled, as is shown for illustrative parameters in Fig. 4-4. There is considerable internal motion of the ground clutter (for example, wind blown foliage) the

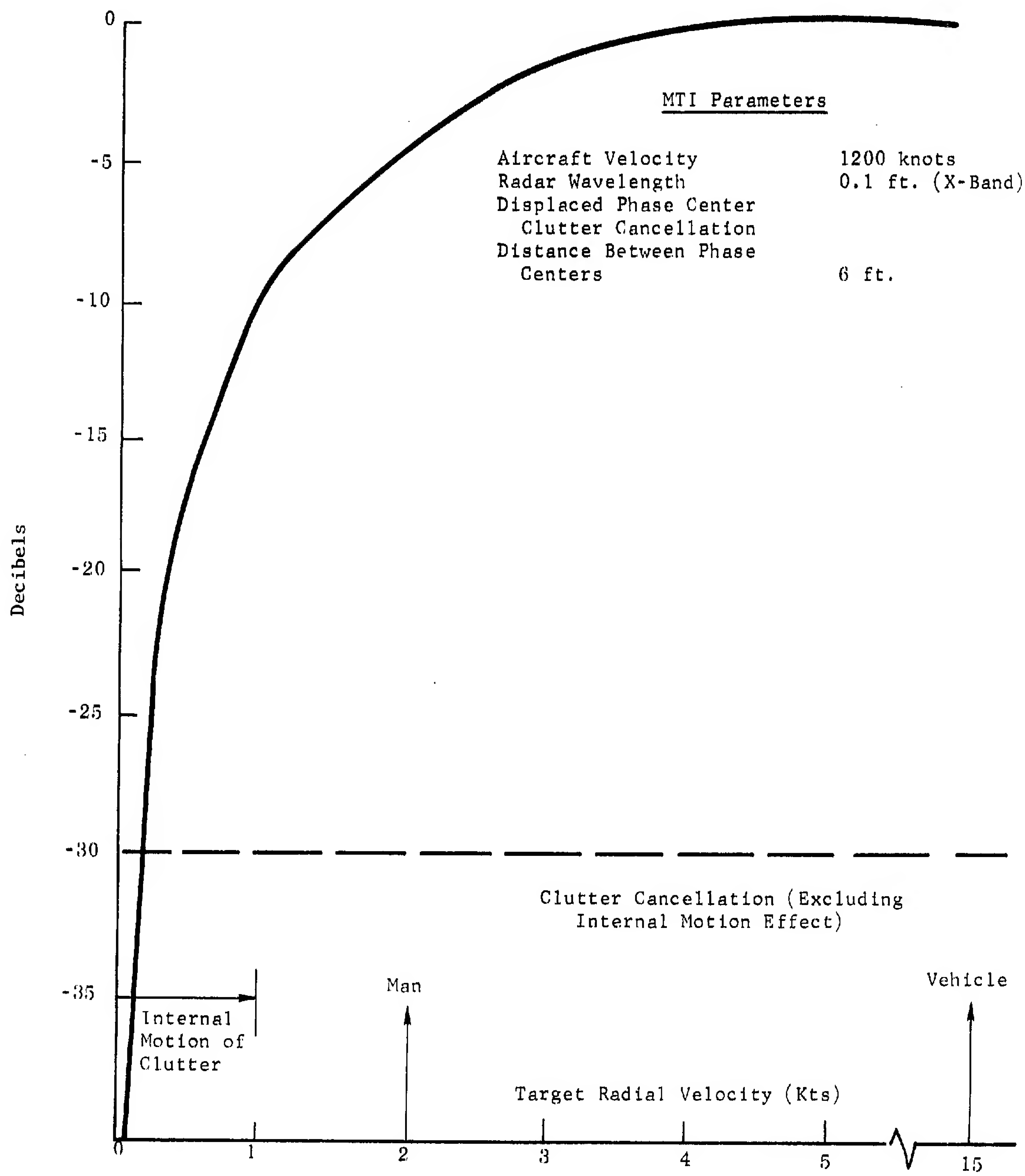


Fig. 4-4 — Signal cancellation for slow moving targets.

clutter cancellation ratio is considerably worse than -30 db. What these numbers mean in terms of actual detection of moving targets is illustrated in Table 4-3. Obtaining fine resolution can be, in itself, an efficient clutter discrimination tool since the target of interest has only to compete with a very small area of ground. Typical vehicles have cross-sections which are greater than a 25 by 25 foot area of average terrain, and that this ratio is increased an order of magnitude by MTI techniques even with 1 knot internal motion. Detection of moving men, on the other hand, is not possible under all conditions when there is internal motion of the ground clutter. Calculations indicate that displaced phase center MTI, in conjunction with a high resolution of 10 to 20 feet, could possibly detect moving men from a tactical reconnaissance aircraft under many conditions. It is reasonable to expect the development and testing of techniques to do this by the post 1967 period.

4.1.2 Pattern Recognition

There are several techniques for airborne data filtering which can be grouped under the title of pattern recognition. These techniques involve the correlation of data, the selection of data and various semiautomatic manual assist features. In the post 1967 era, it is expected, as the basic sensor equipment will become more reliable, lightweight and more versatile, and that a larger percentage of the systems will involve these techniques. A prime function is the selection of priority data for immediate transmission and utilization. Also, if a reconnaissance strike mission is to be performed these techniques are essential.

4.1.3 Long Term Change Detection

Here we refer to a system configuration which allows one to compare two maps, made with independent aircraft flights, and detect any changes in the imaging. The changes can be detected automatically or by visual interpretation aided by data processing.

Table 4-3. Target Radar Cross-Sections

	Actual Radar Cross-Section (sq. ft.)	Typical Radial Velocity Due to Own Motion	Effective Cross-Section After Clutter Cancellation (sq. ft.)
Vehicle	10-1000	15 kts	10-1000
Man	1-10 (est.)	2 kts	0.35-3.5
Grass 100 by 100 ft	20*		0.02-2
25 by 25 ft	1.25*	0-1 kt**	0.001-0.12
Average 100 by 100 ft	100*		0.1-10
Terrain 25 by 25 ft	6.25*	0-1 kt**	0.006-0.62

MTI Parameters

Aircraft Velocity = 1200 kts
Radar Wavelength = 0.1 ft (X-band)
Displaced Phase Center Clutter Cancellation
Distance Between Phase Centers = 6 ft
Maximum Cancellation (Equipment Limitations) = -30 db
Combination of MTI with High Resolution Discrimination

* 6^8 Grazing Angle η = -17 db Grass
η = -10 db Average Terrain

** The 1 kt velocity is for internal motion due to movement induced by wind.

4.1.4 Automatic Signature Recognition

With the present state-of-the-art, image interpretation is largely a manual process, assisted by optical viewing aids and automatic measuration equipment. As the state-of-the-art improves, we may expect more highly automatic aids for image interpretation.

4.1.5 Cross-Section Threshold Indicator

It is feasible to use a cross-section (power return) threshold indicator in conjunction with either the ground mapping or the moving target function of a fine resolution synthetic-array radar. This indicator would serve as an alerting device. Since normal ground return exhibits a large fluctuation of returning power, the false alarm rate would probably be large unless the information obtained by the device was coupled with other indicators such as correspondence to an IR output.

4.1.6 Foliage Penetration

Long wavelength radar is required to "see" targets beneath foliage. Measurement programs are currently being conducted to determine the optimal radar frequency and target detectability using various frequencies. The incorporation of long term change detection with foliage penetration, provides a powerful tool for the detection and recognition of tactical targets "hidden" from optical or high microwave frequencies.

The optimal wavelength for foliage penetration, on the other hand, is not the optimal or even a good frequency for normal high definition terrain mapping or MTI operation. Therefore, a multifrequency radar should be considered, and the tradeoffs between complexity and increased operational usefulness determined.

4.1.7 Data Formats

The high resolution SLR can be used to yield the following types of signals or recorded data:

1. Priority action flags via data link.
2. Raw radar signals of radar imagery via data link.

3. Raw radar signals of MTI via data link.

4. Correlated radar signals of radar imagery via data link.

5. Correlated radar signals of MTI via data link.

6. Raw radar signal film records of radar imagery via recovery from aircraft (processed or unprocessed).

7. Raw radar signal film records of MTI via recovery from aircraft (processed or unprocessed).

8. Correlated radar signal film records of radar imagery via recovery from aircraft (processed or unprocessed).

9. Correlated radar signal film records of MTI via recovery from aircraft (processed or unprocessed).

The above list includes all the possibilities if film is used as the permanent storage medium. Of course, not all these possibilities will be employed in any given system design, and the choice is made during a system optimization procedure.

4.1.8 Priority Information

The priority action flag information which is relayed by data link consists of moving target indication location information and perhaps "large" cross-section target indication and location. This information is used to help in the selection of priority data for immediate transfer to the Priority Analysis Center. The reconnaissance analyst in the Data Display Interpretation Center can also use the location information to restrict the area of search on sensor imagery.

4.1.9 Data Link Transmission

The signals transmitted by aircraft data link are received at the carrier and separated into radar, synchronization, and data block signals. The radar signals are recorded in proper format on film by a CRT line scan recorder. Radar imagery and MTI signals are handled the same and may be time multiplexed. The film record is then photo processed.

If the signals were uncorrelated raw data, then the processed transparency is used as input data to a coherent optical correlator which performs the radar image or MTI filtering. The output signal of the correlator (in the form of a light image) is recorded on film. This output film is subsequently processed, and duplicates made for viewing by the reconnaissance analyst, and for other uses, and storage.

If the signals were correlated on the aircraft, then this step of coherent optical correlation is omitted on the carrier. However, it is probable that raw (uncorrelated) signals will be transmitted via data link.

4.1.10 Removal at the Carrier

When signal films are physically recovered from the aircraft, the same procedure is used as above, with the omission of the data link and CRT recorder. For each case, correlated radar imagery and MTI film records are then available at the Data Routing Center for transmittal to the appropriate analysis center.

5. INFRARED SENSOR SYSTEMS

5.1 INFRARED SENSOR

Techniques for sensing infrared radiation reflected from objects due to the thermal excitation of their molecules have advanced rapidly during the last decade. Figure 5-1 indicates the spectral regions commonly used for sensing infrared radiation and the detector materials often employed. Characteristics of objects of interest for tactical reconnaissance are presented in detail in Section

A thermal image of a scene at normal earth temperatures may be formed with sensors operating in the 3.5 to 14 micron region of the spectrum. Objects at elevated temperatures may be sensed in the 2 to 5.5 micron region.

The infrared sensitive materials may be configured in a variety of ways, ranging from a single element which is scanned over the scene optically, to a two-dimensional image tube containing tens of thousands of elements. Any particular application must consider the geometry, the sensing time, the available infrared energy as a function of wavelength, and a method of data processing and/or display. Infrared reconnaissance devices have usually been of the single element-optically scanned configuration. At the present time, two-dimensional image tube devices are under development, but the presently attainable resolution and thermal sensitivity precludes their use for reconnaissance from high performance aircraft.

Optical scanners for use with single detector or multidetector arrays have been designed which provide equivalent capability to cameras normally used for photographic work. These are the frame camera, in which images of a complete scene are produced sequentially with a relatively short time required to produce each frame; the panoramic camera, which produces successive sweeps perpendicular

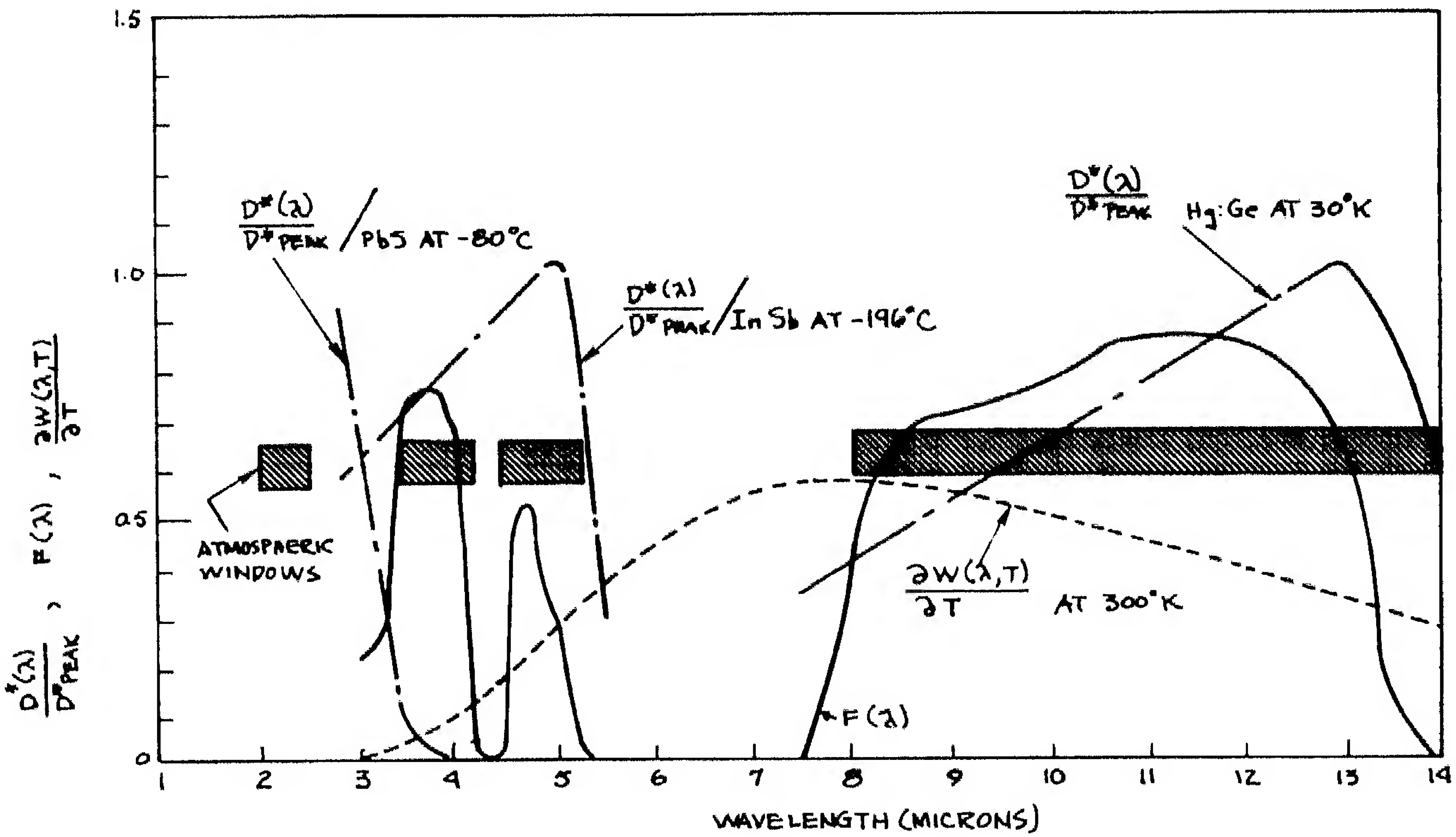


Fig. 5-1 — Plots of detector spectral response $\frac{D^*(\lambda)}{D^*_{peak}}$, system spectral transmission $F(\lambda)$, and the partial derivative of the blackbody radiation function with respect to temperature $\frac{\partial W}{\partial T}(\lambda, T)$.

SPECIAL HANDLING

Approved For Release 2009/12/10 : CIA-RDP67B00657R000300200001-5

to the line of flight; and the strip camera, which produces a continuous image of a strip along the line of flight. The choice of camera type for any given mission will depend upon the required resolution, data redundancy, target characteristics, and mission flight profile. In general, temperature resolution of the order of 0.25°C is required, and spatial resolution of approximately one foot is necessary for recognition of objects of interest for tactical reconnaissance. Useful data however may be obtained with resolution as poor as 10 to 20 feet.

5.1.2 Electronic Signal

The electronic signal which must be sensed derives from minute changes in the electronic structure of the infrared sensing element. The signal may be either generated directly as a voltage or current (as in a photovoltaic detector) or as a change in resistance (as in a photoconductive detector). Additional methods of sensing the change of electronic state of the material have been devised, but are not generally useful in this application.

The electrical signal, usually of the order of a few microvolts, is amplified by a carefully designed preamplifier to raise the signal level to a sufficiently high value, so that additional processing will introduce negligible noise. Usually a separate preamplifier is employed for each detector element; however, methods are being investigated to perform sequential switching at the microvolt level so that only one preamplifier is necessary for an array of detectors. The choice of electronic amplifying technique also depends to some extent upon the type of data processing to be employed. For automated decision making processes where the information to be processed occurs in two-dimensions, it is frequently desirable to maintain channel integrity. Thus, two-dimensional processing may be performed by simple summation of channels to provide one-dimension, and time integration per channel to provide the second dimension.

Technology developments for space applications has made available the capability to have many electronic channels packaged in a small volume requiring relatively small quantities of power. In addition, logical decision making techniques have sufficiently advanced so that several megacycle logical processing is easily within the state-of-the-art.

5.1.3 Signal Processing

Characteristics of targets upon which priority action should be taken may range from simple detection of a thermal gradient, to automated shape recognition. Frame to frame correlation could provide moving target indication and/or thermal variation data. Analysis of target characteristics indicate that almost all of the priority action objects involve thermal radiation well above the ambient background. Hence, simple threshold of a signal proportional to temperature will provide a useful priority action tag. Detection of a particular target may be enhanced by selecting the elemental field of view to be roughly equivalent to the radiating area of the target. Hence radiation from smaller objects in the background will be averaged out and radiation from larger objects will not all contribute simultaneously.

The use of a separate electronics channel for each detector element lends itself easily to threshold processing. Each channel may be thresholded independently, or two-dimensional summation may be employed prior to thresholding. The presence of a threshold crossing may be used to generate signals identifying the time, location and amplitude. This data may then be distributed to the other sensor records or transmitted directly to the user.

5.1.4 Recording Techniques

The large amount of information generated per unit time by a two-dimensonal imaging sensor implies that very high density recording media must be used. Both analog magnetic tape and photographic film are attractive techniques. Other approaches such as thermoplastic tape or two dimensional magnetic domain storage may eventually provide greater storage density, but at the present time their technology is not sufficiently developed.

Storage of photographic film requires that a transducer be available which is capable of frequency response comparable to that of the sensor. Methods currently in use employ glow tubes with optical scanning or a cathode-ray tube display synchronized to the scanner. Neither of these methods are capable of making full use of the high storage density of the film. The glow tube technique is limited to about one megacycle by the frequency response of the tube.

Cathode-ray tubes are limited by the number of resolution elements which can be obtained linearly across the face of the tube; at the present time this is of the order of two to three thousand elements almost independent of the size of the tube. The time constant of the CRT phosphor is also a limiting factor.

A method which appears promising but which has not been thoroughly explored is the use of an array of semi-conductor light sources (light emitting diodes) coupled with an optical scanner similar to that used in the infrared sensor. The frequency response per element is comparable to that of the sensor and arrays of elements of the order of 0.01 inch on a side have been fabricated.

Once the photographic film has been exposed, it may be handled similarly to the film from the photographic sensor. Inflight processing may be employed if access time is important or if some intermediate processing or data transmission is required.

Magnetic tape recording possesses an advantage for infrared sensor storage, in that the quantitative nature of the signal is maintained. However, the linear storage density of magnetic tape is not adequate to record the output of the high resolution scanner at a reasonable tape velocity; hence, it is necessary to utilize the two-dimensional property of the tape. One technique which is particularly convenient for a multichannel infrared sensor is to assign a sensor channel, or a group of sensor channels, to one magnetic tape channel. Additional sensor channels are assigned to additional tape channels. In this way the linear storage density required per tape track is not excessive, and the signals from a scanner having a bandwidth of a few megacycles may be recorded. An alternative technique which is conventionally used for recording televison video signals is to mechanically scan the tape recording head in a direction perpendicular to tape motion. Equipment is presently available having bandwidths of the order of 10 to 20 megacycles and bandwidths of the order of 50 megacycles appear feasible. In addition to the video record additional tape tracks may be made available for recording information such as digital data block or keying data.

5.1.5 Record Storage

Storage of the recorded data aboard the aircraft is usually incorporated into the recording or processing equipment. In the case of the photographic film, record storage occurs at the output of the electro optic transducer, or the inflight processor if one is employed. In the case of magnetic tape, storage is on the tape recorder takeup spool. In both cases the stored record is immediately available upon landing of the aircraft.

5.1.6 Ground Data Processing

Ground processing of the photographic film infrared record is essentially identical to the processing of the conventional photographic record. The film is unloaded from the aircraft, developed if required, and viewed on a projector.

Data storage on magnetic tape may be used to reconstruct a video signal on a CRT display. Alternatively, the information may be fed into a computer and additional keying data generated. If quantitative information is desired by the photointerpreter, this may be extracted from a particular area by using the digital data block and a tape search routine. The desired information is then fed into buffer storage, digitalized, and displayed to the photointerpreter via a synthetic display or typewriter printout.

The magnetic tape handling equipment required on the carrier is basically similar to that employed in the aircraft with the exception that a servo controlled tape drive may be employed to compensate for variations in the airborne recorder, and an additional automatic control and/or search function may be incorporated.

6. ELECTRONIC INTELLIGENCE (ELINT) SENSOR SYSTEMS

6.1 DATA FLOW

Primary data flow and system interconnections for a typical Electronic Intelligence (ELINT) system are shown in the Multisensor System Diagram, Fig. 6-1 the General System Diagram, and Fig. 6-3 the Ground Handling System Diagram. The ELINT system collects target emitter signals, analyzes and interprets them, and provides as an output the identification of the emitters, their geographic locations, and the characteristics of their signals. Although the general data flow is as shown, the specific configuration of the system depends upon the amount of real-time data required, and on the specific needs for which the system will be used. In systems not requiring near real time outputs, the airborne equipment is essentially a collection system, and the major portion of the signal analysis and processing is done in the surface-based equipment. On the other hand, if near real time outputs are required, more of the signal analysis and processing must be accomplished in the airborne equipment. In either case, systems to be used for tactical reconnaissance can usually be less complex, and of smaller size and weight, than systems used for strategic reconnaissance, since they are used against emitters whose frequency bands and basic signal characteristics are already known and are a part of the intelligence data base.

6.2 AIRBORNE

Primary data flow in the airborne ELINT system starts at the "Target Radiation Patterns" block at the left center of Fig. 6-1, continues through the five blocks at the bottom left-hand side of the diagram, and ends at the "Recovery from Aircraft" block in the center. In essence, signals are collected, processed

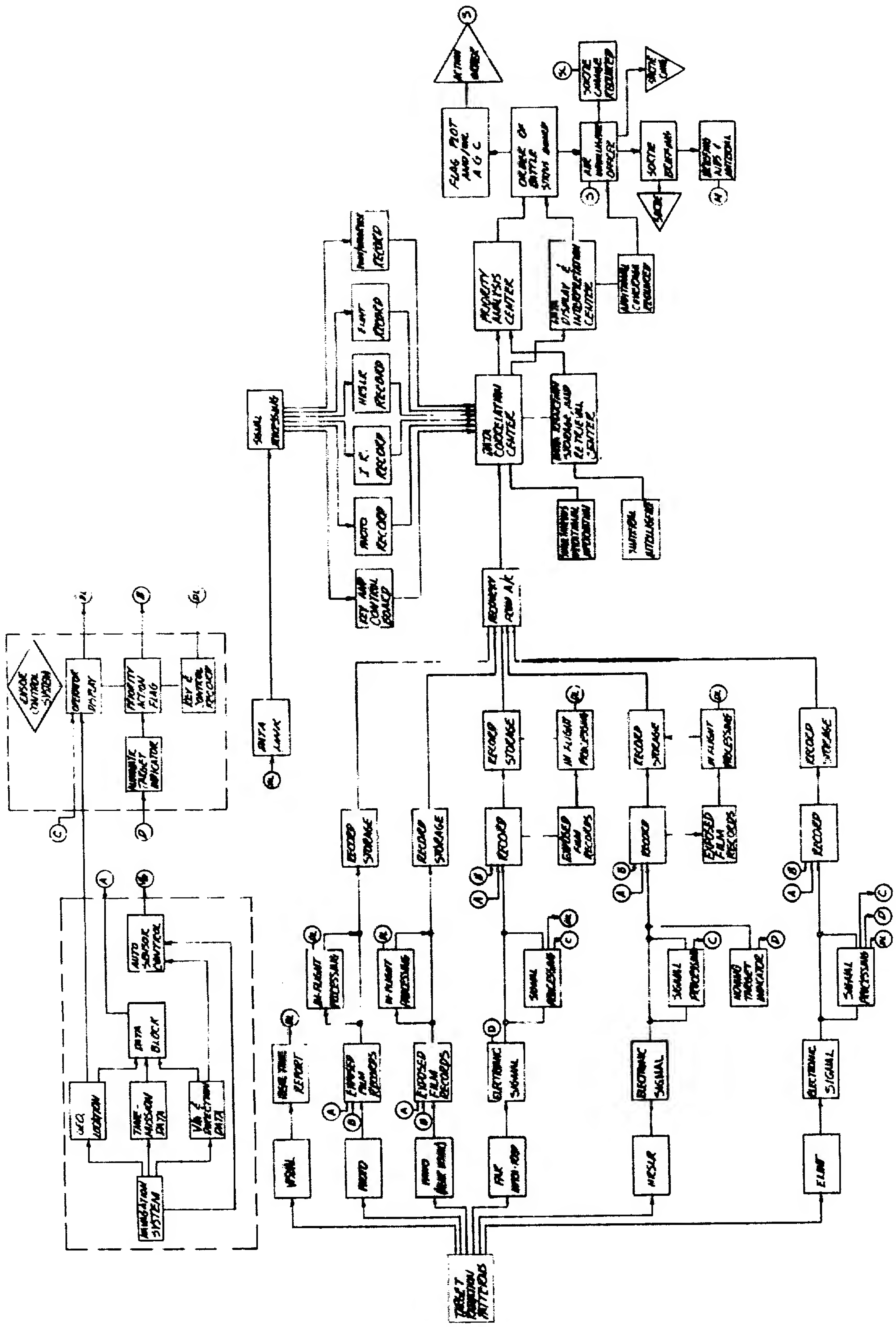


Fig. 6-1 — Multisensor block diagram.

in near real-time for use in the system, and stored on magnetic tape. Collection is accomplished by the use of antennas and receivers covering the required frequency bands. Processing includes the measurement of signal parameters, the comparison of the parameters against apriori data stored in the system so that priority information may be obtained in near real-time, the computation of emitter location, and the coding of all data in a compatible digital format. All signal data are stored on magnetic tape for use in the surface-based correlation center.

ELINT sensors are useful for the recognition and location of targets which intentionally radiate signals within the radio spectrum. Target radiation patterns for the ELINT sensor are only provided for those classes of targets which contain emitters, or which have emitters closely associated with them. The radiation patterns of these targets are partially, of course, the characteristics of the signals radiated by their respective emitters. The signals from an AA acquisition radar, for example, allow this target to be easily identified on a battlefield and differentiated from other targets, without direct observation by an imaging system.

The degree of recognition of specific targets from the characteristic radiation of their emitters depends on the uniqueness of the particular emitter, or combination of emitters, associated with the target. If a specific radar set were installed and used on all of the enemy's motor torpedo boats, a motor torpedo boat would be identified positively whenever its signals were intercepted. On the other hand, if all classes of ships above a certain displacement were to use the same surface-search radar, it would be difficult to identify the specific class on the basis of an intercept from this radar alone. However, each class of ship is usually fitted with a complement of radar equipment peculiar to its functional use, and when multiple intercepts of these emitters can be made, the probability of identifying the specific class of ship becomes very high. Thus, target identification is accomplished by interpreting the "signature" of its emitter complex.

Emitter signal characteristics can be utilized to identify the source of an emission pertaining to the frequency, modulation characteristics, and antenna patterns of the radiator. The following is a tabulation of the parameters which

can be used to identify the emission source. The direction-of-arrival and time-of-arrival parameters are not characteristics which normally could be used to identify an emitter.

Emitters Signal Parameters

Radio Frequency
Pulse Repetition Interval
Pulse Repetition Frequency
Pulse Width
Pulse Amplitude (Signal Strength)
Modulation Characteristics (Non-Pulse)
Duty Factor
Antenna Scan Rate and Pattern
Antenna Beam Width
Polarization
Side-Lobe Level
Intra-Pulse Modulation
Direction-of-Arrival
Time-of-Arrival

A study of these emitter signal parameters has shown that the measurements of frequency and pulse repetition interval (or its reciprocal, pulse repetition frequency) are usually sufficient to provide a rapid and positive identification of most radar types. Pulse width and emitter antenna scan rate are useful in resolving the few remaining ambiguous radar identifications which can occur. To positively identify communications type emitters, it is necessary to measure the basic modulation characteristic of the emitter. Such modulation characteristics as single side-band suppressed-carrier, frequency modulation, pulse code modulation — frequency modulation, and others, can be recognized by the ELINT processing logic.

The ELINT block in Fig. 6-1 represents the equipment used to intercept and collect the radiated emitter signals. The system is comprised of antennas and receivers covering as much of the radio frequency spectrum as is necessary, or

as is practical to cover. Other than communications systems, the majority of battlefield emitters employ frequencies starting at the low VHF range (approximately 30 mcs) and continuing up through 40 gigacycles. ELINT systems, therefore, are designed to cover most of this range, using as many antenna-receiver combinations as required. Since present broadband antenna and receiving systems can only operate satisfactorily over a 2 to 1 frequency range (an octave) or less, approximately 9 to 15 sets of antennas and receivers operating in parallel are required to cover the entire range. Future systems operating with real-time logic and microminiature techniques will be able to do better than an octave coverage per band.

Although collection of target emitter signals may be accomplished over the useful spectrum with antennas of reasonable size, the accurate location of targets is degraded at the lower frequencies because the size of the antennas which can be installed is much smaller than the wavelength of the radiation. Because of this condition, some of the present ELINT systems, for example, do not provide for emitter location at frequencies below approximately 150 megacycles. In new systems being developed, it appears that a lower limit of 30 megacycles will be practical.

At the high frequency end of the spectrum, the radiated power of surface-based emitters is so low, and the path loss is so high, that detection and acquisition from airborne platforms is extremely difficult. The useful limit for new systems appears to be in the vicinity of 15 to 18 gigacycles, thus providing coverage for emitters in K_u-band, but not in K_a-band above 18 gigacycles. However, because of the very short range radar capability at the high frequencies, the latter band is being used almost exclusively for airport surface-detection radars.

Since the operating frequencies of emitters in a tactical battlefield environment are quite often concentrated within several isolated frequency bands, it is possible to simplify the design of ELINT systems, and reduce the amount of hardware required, by covering only a limited number of frequency bands, and using interchangeable plug-in tuning heads to provide the long-term overall coverage. However, the supply logistics required to support such a

concept are so severe that it is not normally done. Therefore, the systems envisioned for multisensor reconnaissance will probably cover the 60 megacycle - 18 gigacycles spectrum.

Determination of the exact frequency range to be covered by an ELINT system follows a detailed examination of the specific emitter environment to be anticipated. Specifications and data for many of the enemy's emitter systems are usually available well in advance of their operational use on the battlefield, so that equipment designs can be predicated on their known and extrapolated capabilities. Histograms depicting the operating frequency of emitters versus their functional use and battlefield utility are used extensively to accomplish this task.

Another design factor of significance to the ELINT emitter collection system is the method used to cover the complete receiving spectrum. Receivers can be of two types - scanning (in frequency) receivers, or non-scanning receivers. In the scanning receiver, very narrow-bandwidth "windows" are scanned simultaneously across each of the frequency bands in repetitive cycles, to sample the emitter radiation present. A receiver of this type will have excellent selectivity, accompanied by very high sensitivity.

The sensitivity of this type of receiver can be made high enough to detect the emission from the side and back lobes of radar emitter antennas at very long ranges. Such a system, thus, can "see" radar emitters regardless of the direction in which the radars are "looking". Because of the frequency scanning action of this type of receiver it does have the disadvantage of not being able to monitor each signal continuously. However, since scan times of 1 to 5 seconds to cover the entire frequency spectrum are easily achieved, the sampling rate is high enough to permit the most sophisticated radar signals to be identified and located.

The non-scanning type of receiver (crystal-video and other types) use contiguous bandpass filters to sample the entire frequency range of the receiver at one time. It has the advantage of providing simultaneous coverage of the frequency spectrum, but its sensitivity is not as high as the scanning type of receiver. Consequently, this type of receiver is normally used to detect only the radiation from the main antenna beams of emitters.

There is a need for each type of receiver, depending on the specific application. For example, systems designed to operate against emitters which, because of their functional use, do not look at the reconnaissance aircraft (shell-trackers, etc.), must have a high sensitivity to intercept the reduced radiation from the minor lobes of the emitter antenna pattern. On the other hand, systems to be used against Early-Warning, GCI, and similar types of radar sets which do look at the reconnaissance aircraft, can, in some cases, use simple crystal-video receivers. With the advent of tunnel diode amplifiers and miniaturized RF techniques, it is now feasible to design "wide-open" type receivers with superheterodyne sensitivities. If one scans the output of each filter bank (miniaturized), before or after amplification, the distinction, for the future, between scanning and crystal-video type receivers disappears. The latter is most attractive because it is passive (has no local oscillators). In any case, it is important that data sampling be done in one way or another, since the unrestricted flow of data would completely choke the processing and recording facilities.

When there is no requirement for extremely high data collection rates, multiple scanning functions are useful. These systems scan in frequency, while using an omni-directional antenna, until an intercept is made, and then interrupt the frequency scan to scan in azimuth. A narrow-beam directional antenna is automatically scanned in the azimuth scan cycle to locate the emitter and complete the analysis. The frequency scan then continues, with interruptions whenever another intercept occurs.

A final consideration of paramount importance in the design of the collection portion of an ELINT system is the type of direction finding system to be employed, and the type of antenna system which it requires. Precise location of the source of an electromagnetic radiation has always been a difficult problem, and in the case of ELINT detection, has been made even more difficult by the extreme frequency range to be covered, the large number of signals to be processed, and the wide range of signal strengths to be experienced.

The location of a source of emitter radiation by an ELINT system involves the solution of a triangulation problem, using the relative bearing angles of the emitter from the reconnaissance aircraft, and a base line established by

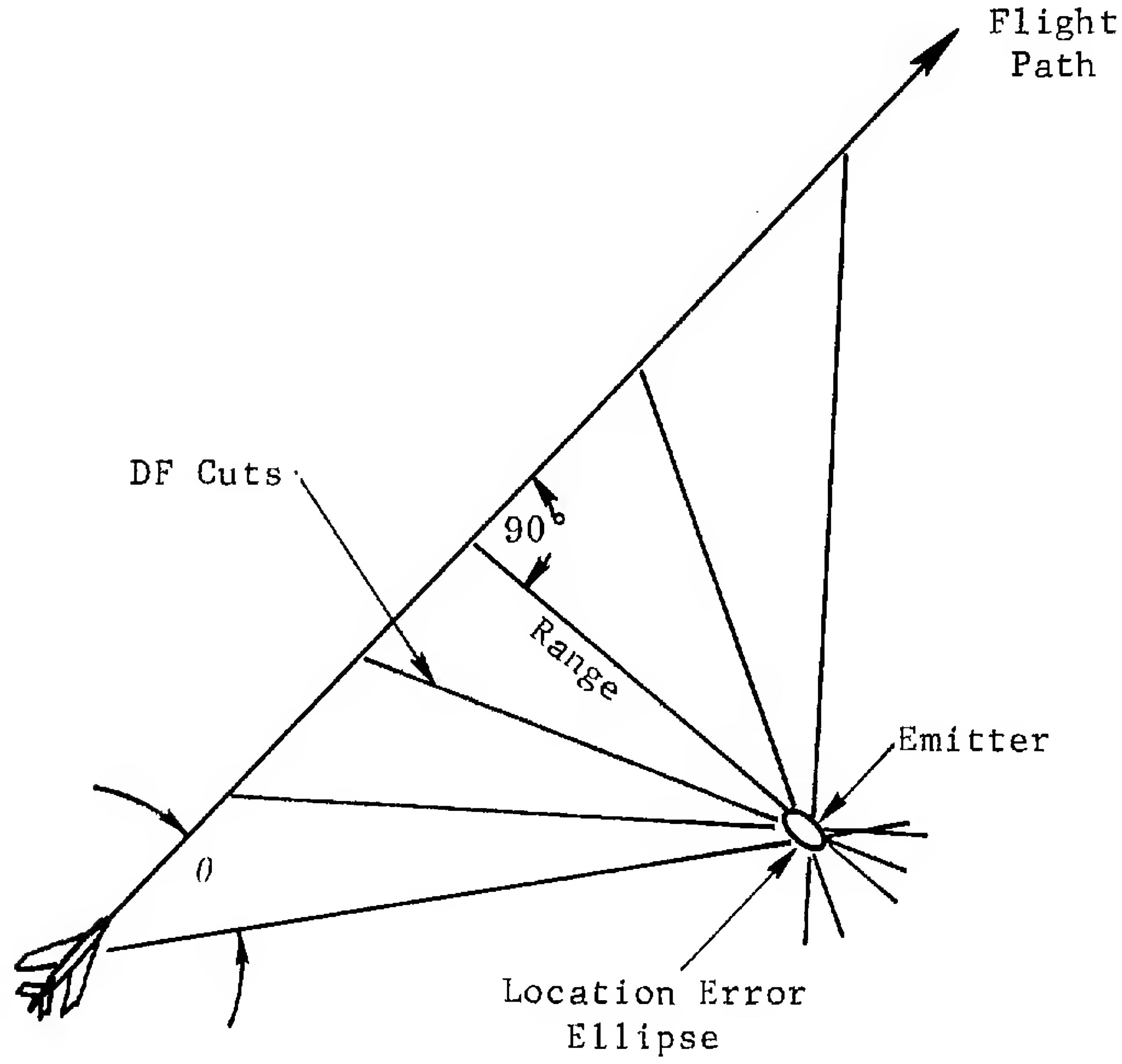
the movement of the aircraft. This technique is necessary because there is no known method of determining the range to a source of radiation when using a single passive receiving system at low altitudes.

The accuracy of triangulation is primarily a function of the accuracy with which the angle(s) of arrival of an intercepted signal can be determined, and the length of the base line between the angles measured. The longer the base line (within limits), the more accurate the "fix" which can be made, since slight errors made in determining the base angles of a very narrow triangle can cause considerable uncertainty of the location measurement.

Airborne ELINT systems generate the base line of the mensuration triangle by "flying by" the emitter source for as long a period as is feasible, as shown in Fig. 6-2a. By obtaining numerous measurements of emitter-bearing angles during the fly-by, not only is the triangulation more accurate because of the more favorable angular relationship, but a large statistical improvement in emitter location is obtained, as well. The statistical improvement is a function of the square root of the number of independent bearing measurements made (θ), and is quite significant when a large number of "DF cuts" can be taken. The area of uncertainty is in the shape of an ellipse, oriented as shown in Fig. 6-2a.

There is also a solution to the location problem which uses the altitude of the reconnaissance aircraft above the earth's surface, in conjunction with measurements of the vertical depression angle from the aircraft, to provide the triangulation. This method is illustrated in Fig. 6-2b. However, this system is only accurate at high altitudes of flight, because, as the altitude is decreased, the vertical angles, (ϕ), become grazing angles which cannot be measured accurately, and the triangle becomes so flat that minute errors in measuring the angles produce large positional errors.

In currently-programmed ELINT systems, using the fly-by technique, emitter locations can be determined within an accuracy of approximately ± 3 percent of the range. The range is the range of the emitter "abeam" to the reconnaissance aircraft (perpendicular to the flight path at the point of minimum range). Accuracies of approximately ± 10 percent of range can be attained by using only a few fixes, without flying by the target.



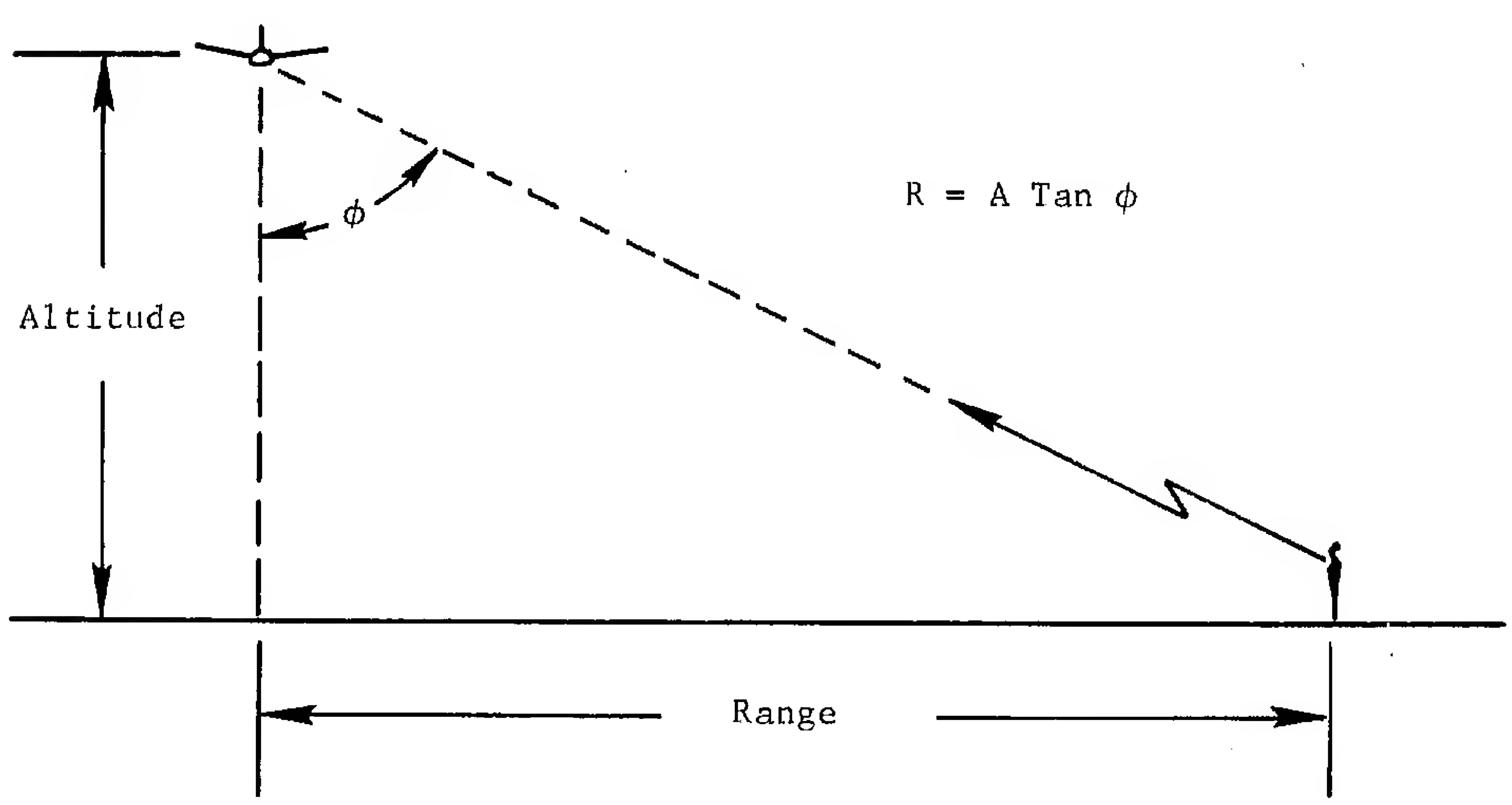


Fig. 6-2 — Direction location using fly-by and AZ-EL techniques.

The emitter location systems using the radio altitude and vertical depression angles, can achieve location accuracies of approximately ±10 percent of range on each pulse, and ±3 percent of range with statistical processing. The vertical angle, ϕ, however, must be larger than approximately 10 degrees to attain these results.

Several techniques are available for measuring the angular location of an emitter from a single reconnaissance aircraft. The basic methods being the measurement of the pointing angle of a rotatable antenna (DF), and the measurement of the phase or amplitude differences of signals intercepted by two antennas (monopulse). The DF method requires a mechanically or an electronically scanned antenna, and is utilized for certain applications where these type antennas can be accommodated. The electronically scanned antenna is a relatively new development which eliminates rotating hardware; however its cost is relatively high, and its extremely rapid scanning rate cannot be utilized because of the necessity of receiving at least three consecutive pulses of an emitter signal for evaluation purposes before it is out of the scanning antenna beam. The accuracy of angle measurement utilizing the DF system varies from approximately ±10 degrees at the low frequencies to ±3 degrees at the high frequencies.

In systems required for high data rate collection, it is not practical to use a scanning antenna in conjunction with a receiver which is scanning in frequency, because the joint probability of intercepting an emitter, resulting from the double scanning process, becomes exceedingly small. For low data rate systems, the dual scanning process can be used successively, an example being the scan-stop-analyze system previously discussed.

The monopulse technique for measuring emitter location angles is most attractive because of its simplicity and small size. In this technique two small antennas, mounted side by side, or separated by a distance equal to several times their size, are used to determine the direction-of-arrival of a wave front by amplitude or phase comparison methods. Moving elements are not required, and direction location information is obtained from each pulse received.

In the amplitude comparison scheme the difference in signal level received at the displaced beams of two antennas is compared to determine the angle-of-arrival of the signal relative to the boresight axis of the composite antennas.

A number of the individual antennas are usually mounted around the aircraft, to divide the space on each side into angular sectors. By logically combining the outputs from all of the antennas, the direction-of-arrival of a signal can be quantized to much less than the size of the sectors. In a typical system a composite antenna on each side of the aircraft, plus one fore, one aft, and one on the bottom of the fuselage, can provide ±42 degrees of coverage on each side, centered about the abeam positions. The resulting angular resolution per single emitter pulse received is approximately ±6 degrees, using antennas with half-power beamwidths as high as 24 degrees. Within the present state-of-the-art it is possible to better this figure. When a number of these angular measurements are made, as the aircraft progresses, the final positional accuracy of emitter location approaches the equivalent ±2 degree angular measurements with this arrangement. Because of antenna size restrictions, the amplitude comparison technique is normally used at frequencies above approximately 2000 megacycles.

The phase-comparison monopulse technique for measuring the angle-of-arrival of emitter radiation detects the difference in phase of each signal pulse received at two antennas, and produces a direction signal quantized to small angular sectors abeam the aircraft, similar to the amplitude comparison system. This system is essentially an interferometer, with the two antennas separated by less than one-half wavelength at the highest frequency in each band, in order to prevent multiple nulls within the coverage angle. In a typical system, a two-element antenna array is mounted on each side of the aircraft, and connected into a phase comparator which provides 12-degree angular sectors over an 84 degree angle on each side of the aircraft, with ±6 degree resolution. The quantization of arrival angle, therefore, duplicates and is compatible with the amplitude-comparison system.

Available space on carrier aircraft usually prohibits the use of the monopulse phase-comparison antennas much below 100 megacycles, where the antenna separation becomes approximately 5 feet. At these lower frequencies the aircraft itself becomes the antenna for receiving signals, but a practical antenna system to provide meaningful directional resolution is difficult to achieve.

At the high frequencies, above 14 to 18 gigacycles, the ability to provide good direction location is limited severely by the large amount of free-space

attenuation which exists, and a number of tradeoffs must be considered. High-gain antennas are needed to counter the attenuation loss, but then the angular view of each antenna is so small that many antennas are required around the aircraft to provide complete coverage. The additional antennas, in turn, require more receiver channels, and thus the system becomes extremely complex. Fortunately, the amount of radiation anticipated at the high frequencies is so limited, that a complex system is not warranted. Therefore, in this frequency range, hemispherical coverage is usually provided by three antennas, one antenna looking to each side, and one antenna looking down. Location is derived by letting the emitter "fly" through one of the beams. The information provided is left, right, or down, with the corresponding time of interception.

6.2.1 Electronic Signal

Processing of data in an ELINT system can be accomplished rapidly and accurately by means of an airborne computer (Signal Processor). Therefore, all of the data collected by the system, in analog or digital form are converted to a standard digital format in computer-compatible language. In the System Diagram, Fig. 6-1, the accomplishment of this function is represented by the Electronic Signal block. The inputs to the block are the signals from each of the ELINT receivers, aircraft positional and navigational data, and timing signals. The output is electronic data in the form of digitally-coded words for use by the signal processing unit (digital computer).

The output signals from the ELINT collection receivers are the pulses from all of the intercepted emitters. Before these pulse signals can be assembled and sorted into pulse trains, which can be further analyzed to identify and locate each emitter, it is necessary to measure the characteristics of each pulse, and identify its frequency, direction-of-arrival, and time-of-arrival. These data are encoded into a single "pulse word" for each pulse, and the sum total of all pulse words constitutes the electronic signal into the signal processor.

In a typical ELINT system the pulse characteristics measured are the pulse width, pulse amplitude, and "special signal" identifier. Pulse width is measured from 0.2 to 90 microseconds and coded in 4 digital bits. Pulse amplitude is

measured over a 60 db range in fifteen 4-db increments, and is coded in 4 bits. The special-signal identifier is a single bit to identify emitters which have CW radiation, or which modulate the carrier frequency within the pulse (pulse compression, "chirp", phase-coding, and others).

The carrier frequency of each pulse is measured by identifying the receiver band from which it was received (coarse frequency), and adding the frequency of that receiver's local oscillator (fine frequency) at the time the pulse was received. Relative frequency can be measured within a precision of 0.1 percent of the frequency spread of a band, which is adequate for signal processing. The absolute accuracy over long periods of time is approximately 1 percent for all bands. Four bits are often used in the pulse word for coarse frequency, and 9 bits for fine frequency.

The direction-of-arrival measurement made by ELINT systems which use the fly-by technique for obtaining emitter site location, is derived in logic circuits that determine in which azimuth sector of the antenna directional patterns the pulse is received. Four bits are used to quantize this measurement, and the resolution is approximately ± 6 degrees in a typical system.

In ELINT systems which utilize azimuth and elevation antennas in conjunction with aircraft altitude to locate emitter sites, as shown in Fig. 6-2, the direction-of-arrival determination becomes a computation of range to the emitter, usually at one specific angle, the broadside angle to the aircraft (90 degrees relative bearing). The range computation is simply the altitude of the aircraft times the tangent of the elevation depression angle to the emitter, and the range output is encoded in 4 bits to a precision of ± 1 nautical mile.

Since timing pulses with a resolution of 1 microsecond are generated within the ELINT equipment, the time-of-arrival measurement is encoded in 10 bits within each pulse word for use in processing signals in the Signal Processor. It is primarily used to make a precise measure of the pulse repetition interval.

The spatial attitude and geographical location of the reconnaissance aircraft (NAV data) are essential in evaluating completely processed ELINT data in the air, or on the ground. Therefore, these data are often encoded with the signal parameter data, included as a portion of the electronic signal, and sent

directly to the recorder as well as to the signal processor. The parameters available in the aircraft include pitch, roll, heading, altitude, latitude and longitude, and they must be encoded in computer-compatible language before routing to the computer or the recorder.

In order to fulfill the data processing requirements in a dense signal environment, the transfer of raw data (individual pulse words of approximately 32 bits each) into the airborne signal processor must take place at a very high rate. Traffic studies have shown that pulse densities over the complete spectrum can run as high as 1 by 10^6 pulses per second. However, because of the sampling accomplished by the frequency or azimuth scanning process, the density seen by the receiver during the "dwell time" only reaches a peak of approximately 30,000 pulses per second. By providing for this rate, therefore, the processing will be compatible with the scanning limitation, and the capability of the system will allow the simultaneous interception of 30 emitters with pulse repetition rates averaging 1000 pulses per second.

6.2.2 Signal Processing

The Signal Processing block in the Systems Diagram, Fig. 6-1, represents the airborne digital computer used in an ELINT system to correlate and process the raw intercept data, so that useful outputs concerning the intercepted emitters may be obtained. A general-purpose digital computer is generally used to accomplish the signal-sorting function, because of the digital nature of the data collection, and the prodigious amount of data which must be processed. However, the required sorting process is inherently different than the type of problem solution for which a general-purpose machine is designed. Thus, a computer designed especially for the sorting task can reduce the amount of input-output interface equipment required with the computer, it can use less memory, and can do the job more efficiently (in less time). Both the general-purpose and special-purpose computers are being used in present systems, depending on the exact requirements.

Since most systems built to date require that the data analysis be done aboard ship, or at a ground base where large general-purpose machines are available, the airborne systems must be configured to operate with these

machines. Under these circumstances, a special-purpose logic unit with a limited capability is used in the aircraft, because the only processing necessary is to properly format the data for the magnetic tape. For future tactical reconnaissance systems the use of identical small-sized general-purpose units in the air and aboard ship will be considered, since their use may provide the most economical and efficient design.

The Signal Processor accomplishes its task by converting the pulse-word input data into "scan words" containing a description of the pulse trains associated with a single emitter. Once the pulse trains from each emitter have been separated and analyzed, the emitters can be functionally identified and their angular location assigned. Incoming pulse words are first sorted into azimuth or frequency scan periods by requiring that scan contributions be from the same antenna-receiver combination. A scan period (or dwell time) is the interval of time during which pulses produced by a particular emitter are received. The scan period for a scanning receiver is the time interval during which the receiver scans through the emitter frequency. The scan period for a wide-open receiver is the time interval it takes for the main beam of the emitter antenna to pass by the reconnaissance aircraft. Initial sorting by this pulse-to-scan correlation reduces the data traffic in the remainder of the computer, and increases the validity and usefulness of the data.

Scan words derived in the Data Processor are the source of signals for all further processing. Contained within them is a precise measure of the emitter pulse repetition rate. Next to the radar RF frequency, this signal parameter is perhaps the most important of all signal characteristics for recognition of targets. When the scan words are matched against stored signal characteristics, emitter types can be identified, alarm signals can be generated, and on-board emitters (OBE) can be discriminated against. Finally, processing of the scan words to digital emitter descriptions provide approximately a 3 to 1, to as high as 100 to 1, data reduction, depending on the pulse repetition rate of the emitter, which makes the recording and/or data transmission problem more reasonable.

Computation of the emitter location must also be done in the airborne Signal Processor if the system is to provide this information in near real-time.

Most of the systems currently in use do not make this measurement in the air, and the computation is done in a computer on the ground or aboard ship. The ELINT system described earlier, which uses the depression angle from the aircraft to the emitter, and the altitude of the aircraft, to solve the location problem, is a notable exception. In that system, the solution of the ranging triangle is derived in the airborne computer in near real-time, and is stored on film for immediate viewing. It is very probable that new ELINT systems for tactical reconnaissance will also be required to furnish the location of preselected emitter types in essentially real-time.

A final function of the Signal Processor is to format and time-multiplex the variety of digital information required for the data link recorder, operator's display, and auto-target indicator. By so doing, the volume of digital information relayed to the ground, or recorded, can be reduced substantially, and the operator's display optimized with respect to data presentation. The routing of these output signals from the Signal Processor is shown in the System Diagram, Fig. 6-1. Complete data on all emitters are sent to the tape storage, while priority and selected data are sent to the automatic target indicator, data link, and operator's display, if these devices are used.

6.2.3 Record and Record Storage

In the majority of ELINT systems manufactured to date, the output information from the system is recorded on magnetic tape. Only a few systems record on film, there being a need in one system for real-time readout of ELINT and other sensor outputs on film in the aircraft. The tape storage is, of course, ideal from many standpoints, and most probably its use will continue in new designs of the future.

ELINT data may be readily encoded and stored on magnetic tape, because the data rate of the information, after processing by the computer, is quite reasonable. Thus, although a maximum of 30,000 32-bit words of raw data per second can be present at the input to the data processor, there is considerable redundancy in this information, and the corresponding output after processing may be represented by less than 500 32-bit words per second. In typical systems a one-inch wide tape with 16 recording tracks is used, and the information

is recorded at a density of 1000 bits per inch, at a tape speed of 7.5 inches per second. At this recording speed more than 3 hours of flight-time may be stored on a 14-inch diameter reel.

In addition to the emitter characteristics and timing signals, other data pertinent to the mission are also recorded on the tape, as was discussed earlier. These items pertain to the status of the system, and include navigation weather and fixed data. The priority need for most of this information, however, is not very high, and it is not necessary that it be recorded at a high data rate on the tape. Required data recording rates vary according to the use of the data, and it is a function of the recorder electronic equipment to multiplex these signals properly. Representative of the data sampling rates employed in current ELINT systems are the following:

Fine Frequency - every 8 milliseconds
Mission Time - every 131 milliseconds
System Status - every 500 milliseconds
Navigation Data - every 1 second
Weather - every 134 seconds
Fixed Data - every 268 seconds

Randomly arriving emitter characteristic data are placed in storage and recorded between the periodically-sampled data.

The ELINT system which utilizes film as a recording medium is a near real-time system, requiring identification and location of approximately ten emitter types whenever they are intercepted. A 5-inch film strip is used to record this information in a remarkably simple display format. Identification and location of each emitter is annotated on the film strip by means of a single letter of the alphabet placed on the film at a distance proportional to the range of the emitter, and at the time that it passes abeam the aircraft. The usable dimension across the film strip is 4 inches and represents the cross-course range of the emitter from the aircraft. Distance along the film designates the position of the aircraft (and emitter) in time, since the film strip is moved in synchronism with the aircraft at the proper scale rate. Ten letters of the

alphabet are used to define ten categories of emitters (GCI, FC, etc.). An unknown emitter is designated by the letter "U".

A display of this type is extremely easy to interpret, by even a busy pilot or observer, and it does provide a permanent record for a limited amount of electronic intelligence data. It is not as versatile a storage medium as magnetic tape, or as convenient to use, because of the developing and processing required.

6.2.4 Automatic Target Indicator

During the process of correlating pulse-words to form scan words, and thereby identifying emitters, the signal processor is continually matching signal parameters from one scan interval to the next. Therefore it is possible to program the computer so that it can recognize the presence of a particular set of signal parameters, and generate an alarm or indicate a priority, as desired. The a-priori information used for this purpose can be a single emitter parameter, or a combination of parameters, which uniquely identify the emitter source. Although several parameter combinations are useful for this purpose, the emitter RF frequency and pulse repetition interval have been found to provide a positive identification in a majority of cases. This relationship is discussed more thoroughly in the Multisensor Tactical Target Study.

In some ELINT systems, the recognition of prescribed emitters is used to provide an operator alarm. The reception of a specially-coded pulse, or a CW emission, for example, are characteristics frequently used to trigger this alarm, the object being to cue the operator so that more detailed measurements of the particular characteristic can be made.

In a tactical reconnaissance system the a-priori target data inserted in the Automatic Target Indicator will be for the purpose of selecting important tactical targets to be identified and located on the operators' display, or used to establish priority data flow paths. In fact, it is very likely that the automatic targeting will be accomplished back in the Signal Processing block in Fig. 6-1, so that the same preselection of emitter types can control the outputs to the data link and airborne recorder. Rather than being used to

provide an alarm function, the a-priori data in a tactical ELINT system will be used as a final filter of emitter characteristics, to restrict the output data to high priority targets of tactical concern.

6.2.5 Operator Display

Several types of operator displays have been used successfully for real-time evaluation of emitter characteristics in the reconnaissance aircraft. Most often the displays have been of the panoramic type on a multiple-trace cathode-ray tube, displaying to the observer the signal parameters versus frequency scan. This type of display is designed to be used primarily for technical analysis of emitter signal characteristics, and does not lend itself to the rapid identification and location of selected emitter types, as is required for real-time tactical reconnaissance. In recent years this type of display has been markedly improved by the use of cathode-ray storage tubes in place of the conventional tube. The direct-view storage tube is a cathode-ray tube into which information is introduced as an electrical signal and read out at a later time as a visible output corresponding to the stored information. The characteristics that make this device attractive for this application are its brilliant, non-flickering, uniform display, and its ability to control the display persistence.

A second type of display which has been used is a cathode-ray tube image of the data stored on film. A 20-inch diameter tube is used in one system to provide a 4-times size enlargement of the output film record in essentially real-time. In this particular case the display is designed for tactical use, and only the type and location of preselected emitters is displayed, as was discussed previously in the section on recording.

Plotting board displays are used frequently in ground and shipboard installations of ELINT processing equipment, but are not being used in the air. Such plots are essentially Radar Order of Battle (ROB) plots, displaying type and location of preselected emitters. Small, rugged plotters are available which could be used in airborne installations for this purpose, and it is possible that future tactical reconnaissance systems may use them because of the real-time information which can be obtained. However, it is very likely

that a direct-view storage tube would be used for the plot in a multisensor system, because of its greater flexibility, and its capability of being used with the other sensors.

In any type of display to be used with a multisensor tactical system, the basic requirement is that the high priority ELINT information be presented in a clear, concise manner as rapidly as possible, and that its format be integrated with the other sensor displays so that the observer can rapidly assess the over-all situation. Human engineering factors are extremely important in the design of such a display if the ultimate in man-to-machine efficiency is to be attained.

6.2.6 Data Link

ELINT intelligence data collected in the air and stored on film or tape may be transmitted to ground or surface-based intelligence centers by means of a data link, if this should be required. Although the design of reliable links for this purpose is difficult, when high quality data from imaging-type sensors must be transmitted in real-time, the requirements are not as severe in the case of data derived from ELINT systems, and more conventional radio links can be used. The difference stems from the amount of bandwidth required to handle the information content of the imagery. The number of information bits in a photographic type of image is very high, and relatively large bandwidths must be used to transmit a reasonably faithful reproduction. ELINT data, having been predigested by the airborne computer to eliminate its redundancy, requires much less bandwidth for reliable transmission.

If the amount of emitter data being stored on magnetic tapes by present ELINT systems is used as a criterion for estimating the data link bandwidth requirements, it will be found that approximately 1 megacycle of video bandwidth is required at normal tape speeds. As was discussed in a previous section, the information stored on the tape includes system status, timing signals, mission parameters and Navigation data, as well as the scan and emitter words for intercepts.

Since a video bandwidth of 1 megacycle has too much information content to enable the ELINT signal to be transmitted over standard communications links in

real-time, methods of reducing the bandwidth further have been investigated. For example; if the data stored on the tape is restricted to emitter type and location, omitting the scan words containing pulse characteristics, the bandwidth required can be reduced to less than 1 kilocycle, and real-time transmission directly from the signal processor can be accomplished.

6.2.7 Recovery from Aircraft

The recovery of ELINT reconnaissance intelligence from the reconnaissance aircraft requires simply the removal of the tape reel, or film spools, from the ELINT equipment. On carrier-type aircraft convenient hatch covers are provided on the ELINT pod, so that the tape reel can be removed from outside the aircraft immediately after it lands. In a typical system 14-inch diameter flangeless reels, holding 8400 feet of 1-inch wide magnetic tape, are used in the aircraft. These tapes are later broken down into 10 1/2-inch diameter flanged reels for processing in the ground computer.

When film is used, it has either been already developed and processed (for the inflight viewers), or is an undeveloped negative. In one system, installed in a large experimental aircraft, both developed and undeveloped 5-inch wide film is used, in lengths of 250 feet on 5-inch diameter spools. The developed and processed film may be removed on the reel and used as is. To retrieve the undeveloped film, it is necessary to remove the entire film magazine and take it to a dark room for developing.

6.3 SURFACE BASED

Illustrated in Fig. 6-3 is a representative multisensor system network for a surface-based reconnaissance data processing center. The diagram covers all phases of the multisensor data processing cycle, from acquisition of the input data through the analysis of the intelligence output. The diagram also depicts many of the possible subsystem interconnections which could exist. The data flow for the surface-based portion of a typical ELINT reconnaissance systems is contained within this network, and will be discussed in the following paragraphs. Fundamentally, the system reduces the collected data from the reconnaissance aircraft, and transfers the information into a computer where it is

analyzed and correlated with the available data base. The intelligence data are outputs on a teletypewriter and digital plotter which may be used immediately or for the long-term updating of the data-base library. The specific output data include definition and location of emitters, correlation with the Electronic Order of Battle, plots of emitter location and the aircraft flight path, reports of location, and reports of emitter activity and priority points.

The basic ELINT system consists of the 9 blocks located in the left central portion of Fig. 6-3, starting at the ELINT RECORD block at the left, and proceeding across to the PLOTTING BOARD near the RECONNAISSANCE ANALYST. Since the major attention will be directed to this portion of the overall network, it is repeated in abbreviated form in Fig. 6-4.

6.3.1 ELINT Record

The prime image record from airborne ELINT systems has been photographic film or magnetic tape. Since the film is used in very few systems, only the use of the tape will be considered in the ground-processing systems to be reviewed. In a typical system a 14-inch diameter reel, containing 8400 feet of 1-inch wide tape is used. If full processing has not been done in flight, the emitter data on the tape will be in the form of digital pulse words. Complete processing must, therefore, be done in the surface-based complex.

6.3.2 ELINT Reduction

In ELINT systems being used today, magnetic tapes received from a returning aircraft are rewound on 10 1/2-inch diameter flanged reels, using a magnetic tape rewinder. A flangeless reel is used in the airborne unit to get a large capacity within a small space, but flanged reels are required in the ground processors to enable a "start-stop" processing technique to be used.

The rewound airborne tape is placed in a magnetic tape processor with other tapes containing computer programs, Electronic Order of Battle (EOB), Emitter Parameter List (EPL), and a final output tape. The airborne tape is then subjected to four stages of processing to determine the location and characteristics of the emitters which were intercepted on a given mission. These stages

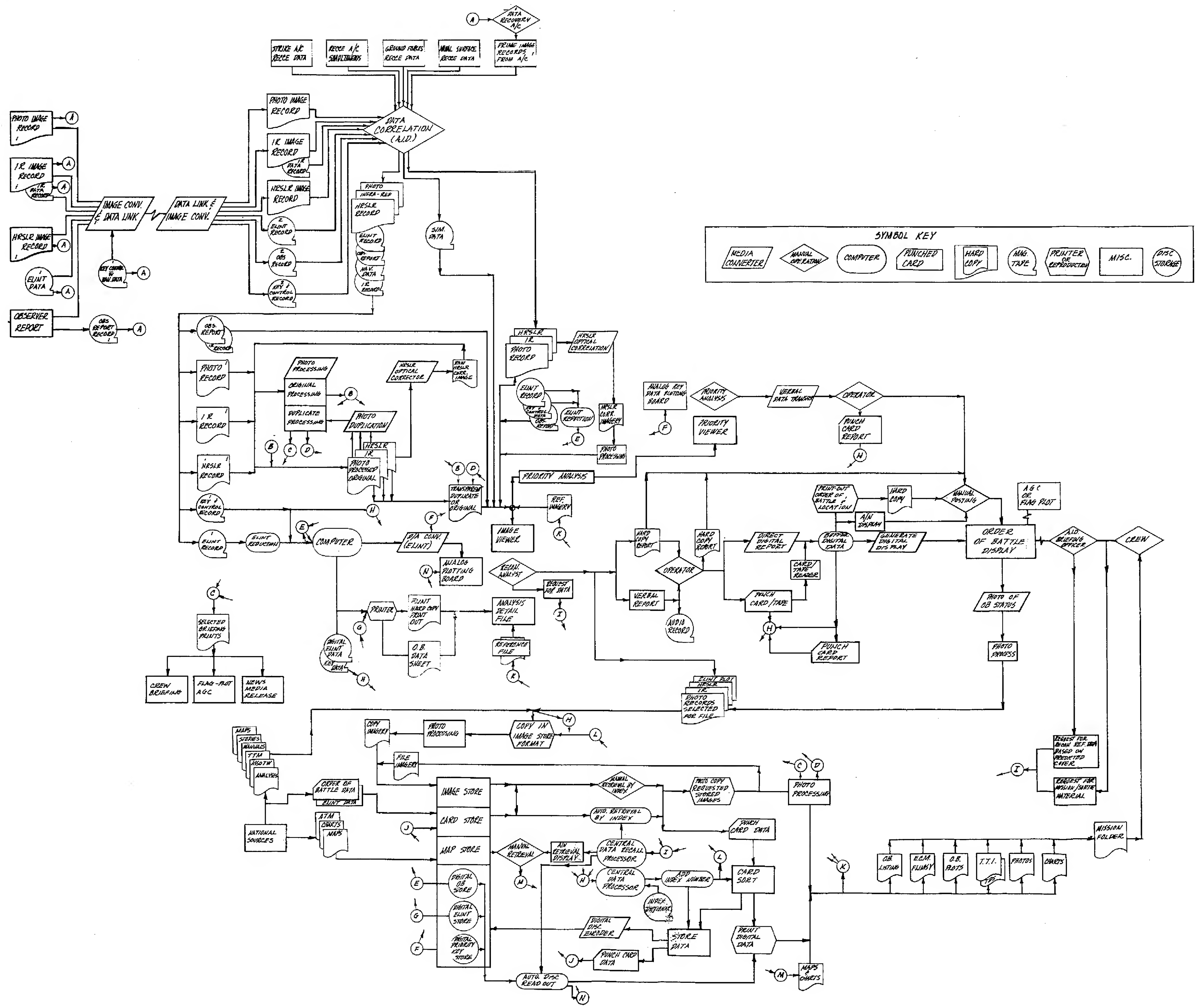


Figure 6-3 — Detailed breakdown of signal flow in the reconnaissance center.

Approved For Release 2009/12/10 : CIA-RDP67B00657R000300200001-5

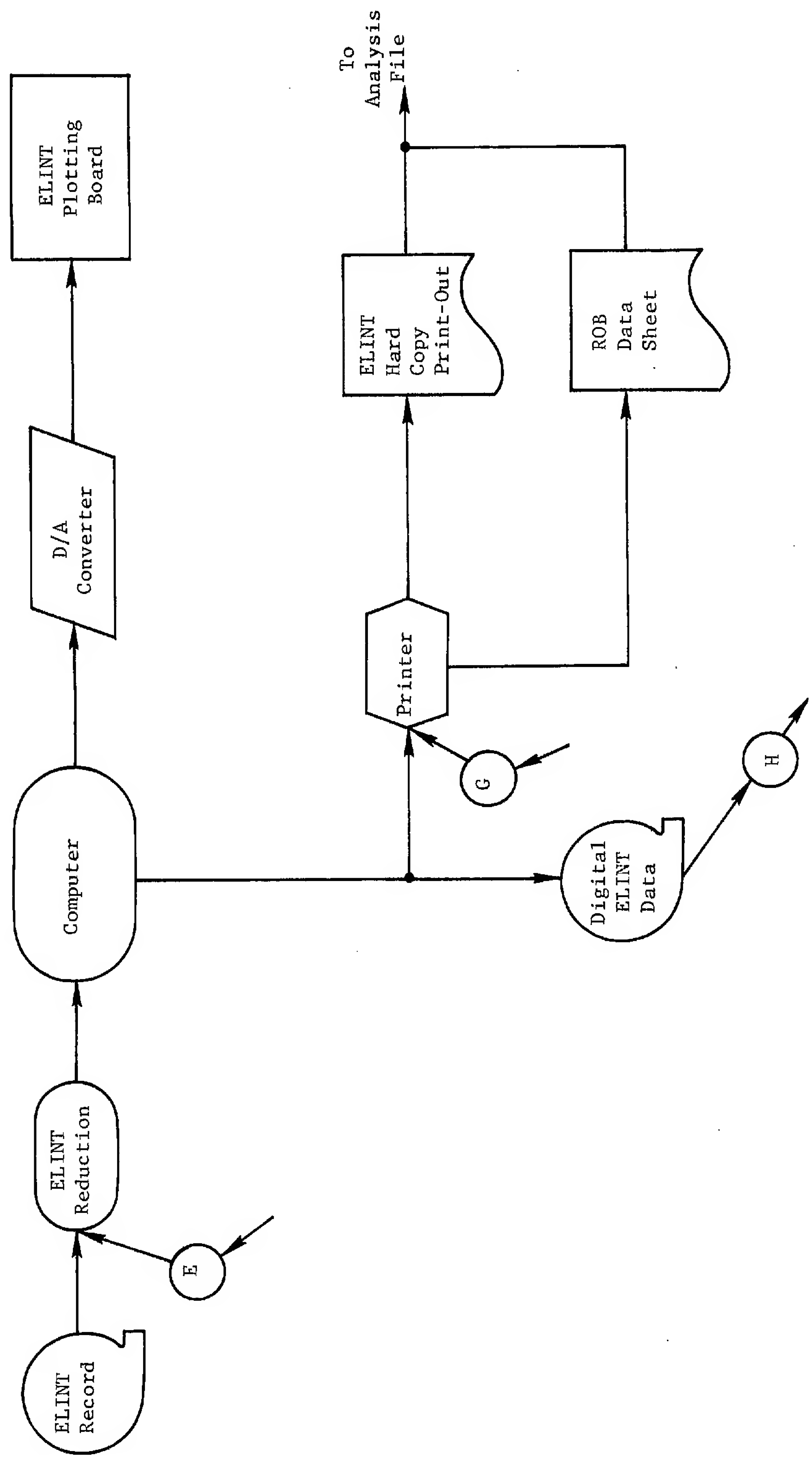


Fig. 6-4 — Basic ELINT processing surface-based.

are scan word formation, emitter word formation, emitter location, and output report. The flow characteristics of this data reduction are shown in Fig. 6-5.

During the formation of the scan word, the raw data taken from the airborne tape are separated into lists to segregate pulses which were detected from each emitter in one scan period. An electronic definition table (EDT) containing the RF frequency and pulse-repetition frequency of known type emitters is utilized to separate and identify the pulse trains constituting each emitter. After a pulse train has been assembled and identified, the pulse parameters of that emitter are added to the pulse repetition frequency to make up the contents of a scan word. Upon completion of this process for the entire airborne tape, a scan word tape is generated containing all of the scan words formed, along with the navigational data of the mission. The scan word tape is then used as the input to the second processing stage, which provides for emitter word formation.

The emitter word formation program correlates emitter data on a scan-by-scan basis which combines all scan words obtained from the same emitter. Various sorting criteria are used for this to ensure positive identification of the emitter. The output of the emitter word formation is an emitter word tape which contains the signal characteristics, orientation of the reconnaissance aircraft, and the quantized angular bearing of the emitter from the aircraft during each scan.

The emitter word tape is used to locate each emitter from the angular bearings measured during each scan. This is accomplished by properly weighing the measured bearing angles and finding the least squares distance from all of the bearing lines at their convergence. Figure 6-6 indicates the manner in which location is determined, and illustrates the fifty percent probability ellipse (area) within which the actual location of the emitter lies one-half of the time. This ellipse is defined by the lengths of the semi-major and semi-minor axes and the orientation of the major axis from true north.

6.3.3 Computer

A general-purpose computer is used in conjunction with the various data and programming tapes to reduce the collected data from the reconnaissance

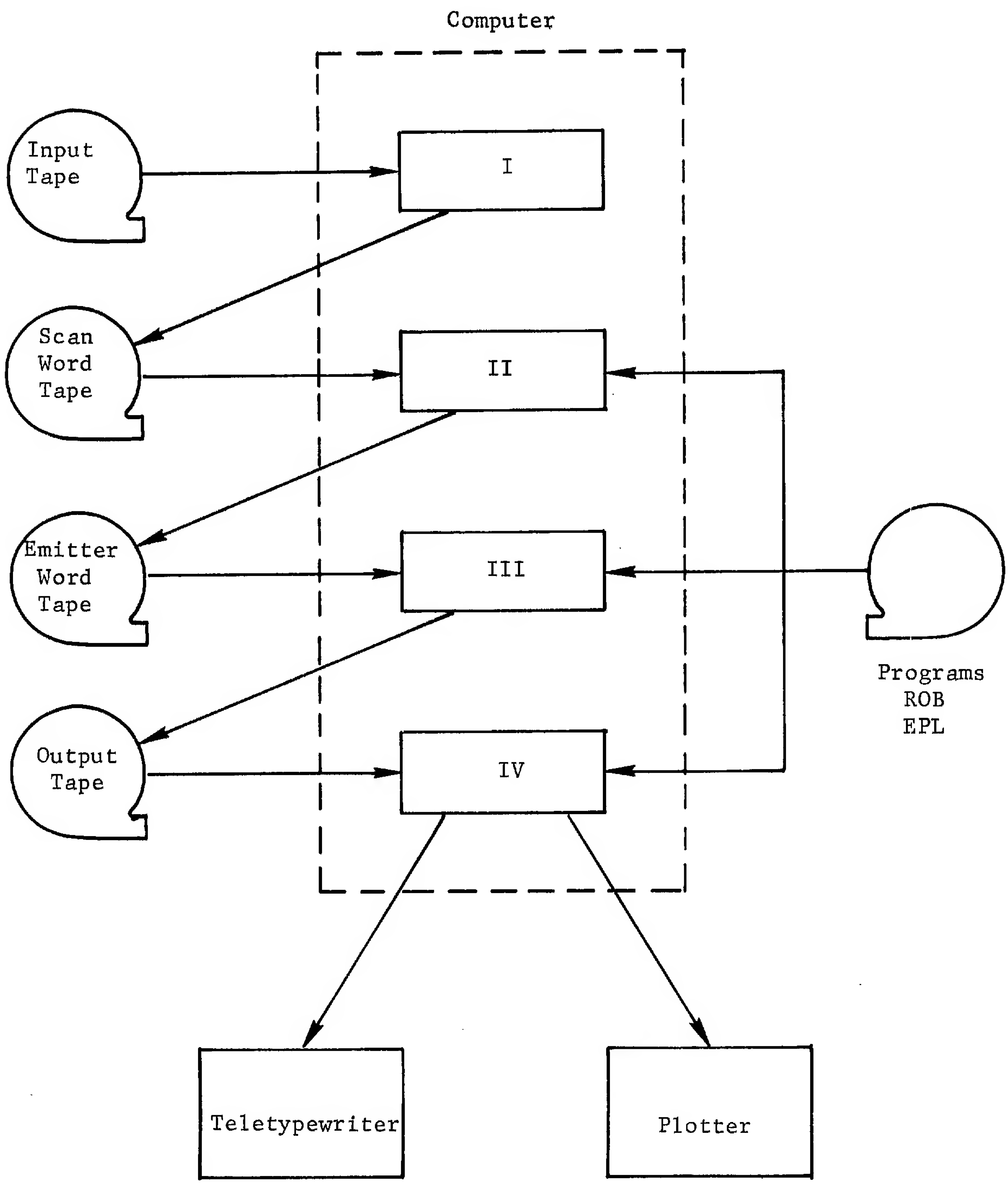


Fig. 6-5 — Data reduction cycle.

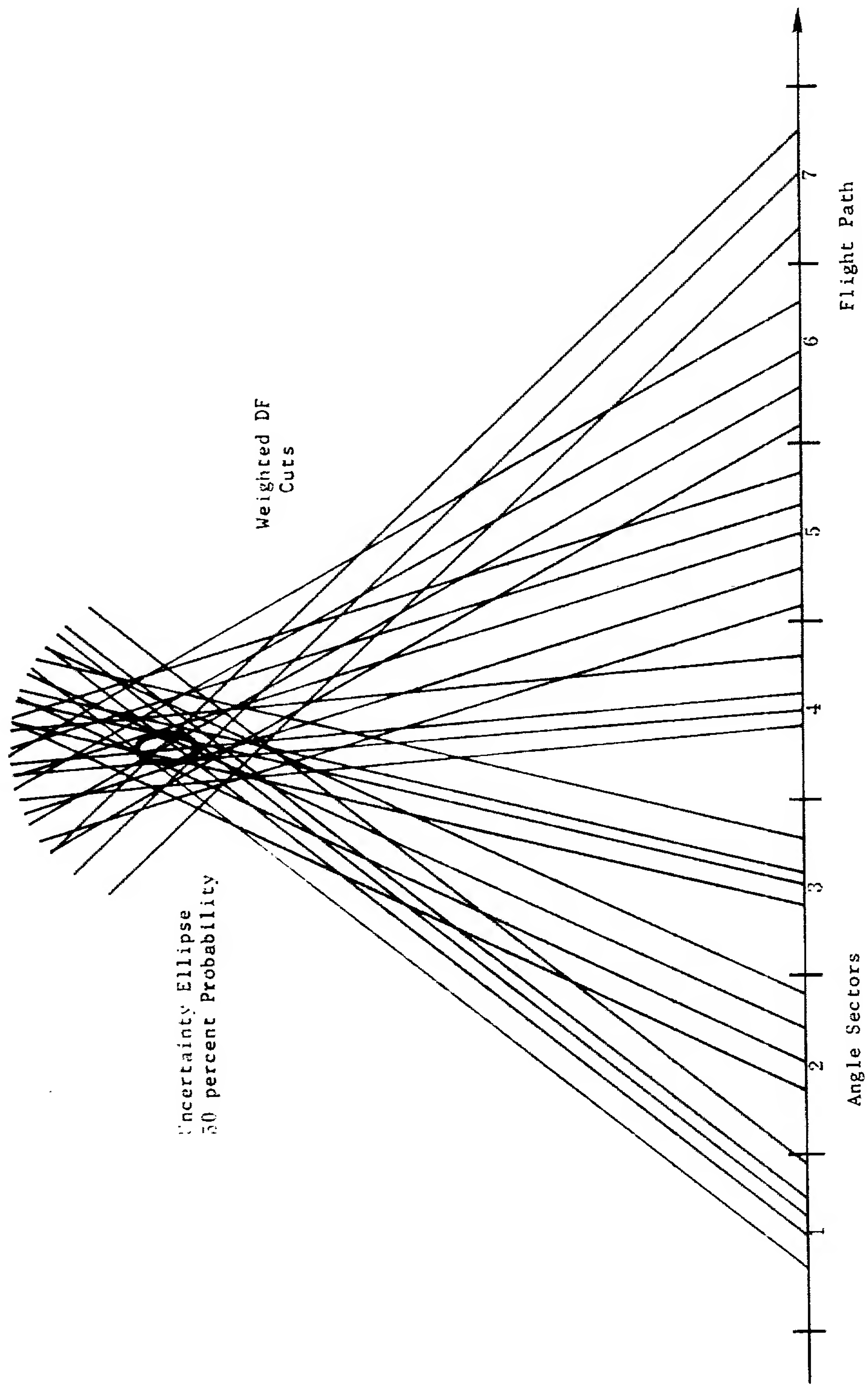


Fig. 6-6 — Emitter location.

SPECIAL HANDLING

Approved For Release 2009/12/10 : CIA-RDP67B00657R000300200001-5

aircraft. A typical computer for this application is a general-purpose, stored-program machine capable of processing a large quantity of complex data very rapidly, and which provides rapid communication with external devices. It has a large random-access internal storage. The normal computer operation may be performed by manual initiation of the automatic programming and does not require monitoring thereafter.

At the conclusion of the final tape formation in the four-stage data reduction sequence, output data in the form of hard copy teletypewriter print-out and plotting board locations are available. Several methods of presenting the data are provided in order to cover various mission requirements, and the computer is preprogrammed before the data reduction run to accomplish this. Programs generally used include General Processing, Emitter Activity, Priority Point Activity, and Area Activity. The format of the data print-out associated with these computer programs will be discussed further.

General Processing is used for airborne tape data reduction when all emitters are to be processed without excluding any emitters on a geographic basis. The output is generally a two-line teletype message, which indicates the emitter characteristics, plus its most probable location. The location is also plotted on the plotting board and labeled with an index number which corresponds to the emitter number on the typed output. An annotated example of a teletype print-out is shown in Fig. 6-7.

The computer program for Emitter Activity filters the processing cycle so that only those signals having characteristics selected by the user are processed and printed out. The characteristics which can be pre-specified are usually the frequency band, frequency, PRF and the minimum number of pulses to be processed. Outputs of the Emitter Activity program are the same as those of the General Purpose program except that they are restricted to signals of emitters falling within the selected limits.

The Priority Point program permits only that emitter data which originated at a particular geographic point (are) to be processed. Latitude and longitude of the point, plus the radius of the area of interest are inserted into the computer with the priority point program. The outputs will include only those emitters that fall within the desired target radius.

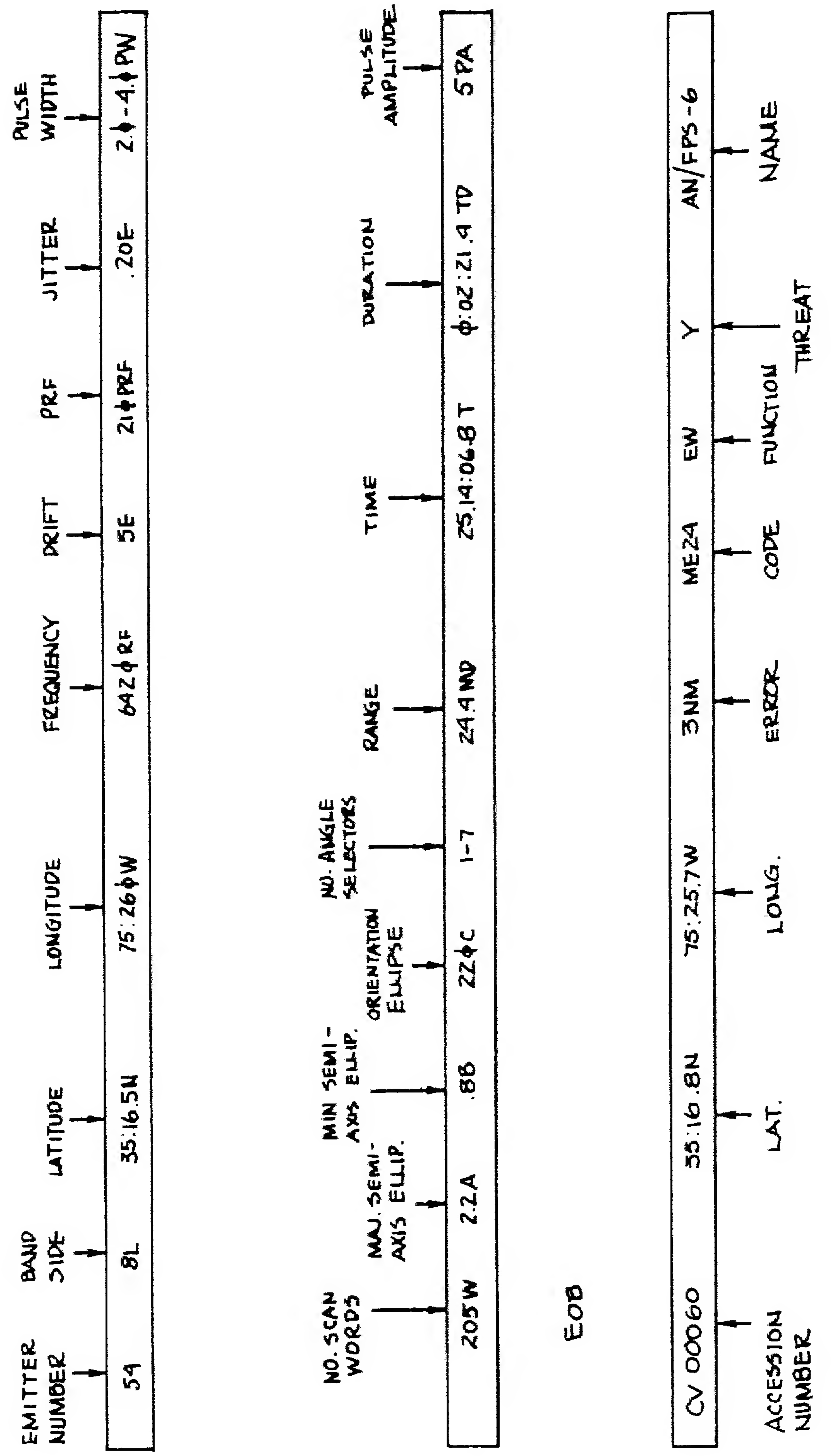


Fig. 6-7 — ELINT teletypewriter printout.

The Area Activity program has the same function as priority point activity, but prescribes an area bounded by straight lines rather than by a circle. The latitude and longitude of as many as 40 different points may be selected for this program, and only signals emanating from the area enclosed by straight lines connecting consecutive points will appear in the final output listings.

Other programs are available which may be used in conjunction with each of the primary programs to provide additional flexibility. An Electronic Order of Battle/Electronic Parameter List correlation (EOB/EPL) is one that is particularly valuable. The correlation is done in the computer by comparing the information on the final data tape with the data base EOB tape. The correlation is attempted for only those emitters being processed in accordance with the primary program, and the output results in additional teletype lines below the standard two-line print-out, which delineate possible EOB or EPL correlations. During the correlation process the computed CEP ellipse is expanded three or four times to make allowances for errors in locating the emitter, or errors in the ROB. A typical EOB correlation print-out is shown as the lower line in Fig. 6-7 below the ELINT intercept data.

Although the simple programs discussed above would probably furnish as much data as would be useful, or could be handled in a tactical reconnaissance system, the availability of the general-purpose computer makes it very convenient to use other types of computer programming routines periodically for the extraction of statistical data. In one large ground-processing system, for example, over fifty different programming routines are being used to derive long-term intelligence from mission and EOB tapes. Periodic analysis reports, site-set correlations, confirmed sets reports, inventories, and related information, are typical of the diverse intelligence data obtainable in this manner.

Several small-sized general-purpose computers are currently available to handle the ship-based data reduction process. Some of the salient characteristics of these machines are the following:

1. Internal high-speed storage with a cycle time of 8 microseconds.
2. A storage capacity of 32,000, 30-bit words.
3. A library of 62 instructions, most of which provide for conditional program branches.

4. An average instruction execution time of 10 microseconds.

5. Optional operation with a 15-bit half word.

6. Programmed check of data priority.

7. Signal address instructions with provisions for address modification via seven index registers.

8. Internal seven day real time clock for initiating operations at prescribed times.

9. Fourteen input and 14 output channels.

10. A "bootstrap" memory containing two, 32-bit word memories.

6.3.4 Printer

The primary output data from the computer is the hard copy print-out on a teletypewriter, samples of which were shown previously. These machines can print-out data at a speed of up to 10 characters per second, and with their paper tape attachments, function as the connecting link between the operator and the computer. Some of the functions which the teletypewriter equipment can perform in the data-processing system are tabulated here:

1. Enter keyboard data into the computer.
2. Enter punched-taped data into the computer.
3. Print hard copy from computer data.
4. Punch paper tape from computer data.
5. Perform items 3 and 4 concurrently.
6. Print hard copy from keyboard data.
7. Punch paper tape from the keyboard data.
8. Perform items 6 and 7 concurrently.
9. Print hard copy from paper tape data.

It may be noted from this list of the functional uses of the teletypewriter that it is indeed a versatile piece of equipment and vital to the operation of an automatic computing facility.

6.3.5 ELINT Plotting Board

Although a Digital-to-Analog converter is shown located between the computer and ELINT plotting board in the multisensor surface-based network, Fig. 6-3,

the conversion is conveniently done inside the plotter, and modern-day plotters for this application are considered to be digital plotters. A size of approximately 3 1/2 feet by 5 feet is convenient, since it can accommodate standard military map and chart sizes. Usually the plotting is done on opaque paper or transparent overlays, and a vacuum system is provided to hold the plotting material flat on the board.

Operating in conjunction with the digital computer the plotter also has a great deal of flexibility, and can be used to prepare plots of the reconnaissance aircraft flight paths and define the preprogrammed areas of data retrieval. Plotting may be in the form of a continuous point plot, symbol plot, or a combination plot of points and symbols. The points may be plotted at a rate of more than 60 per minute with an accuracy of 1/64th of an inch of the commanded position. Some plotting boards are equipped with a magnifying eye-piece for accurate positioning of the maps and overlays.

6.3.6 Data Base Library

In the overall system network, Fig. 6-3, the data base "library" is shown just below the basic ELINT system in the central data processor for annotation prior to storage.

6.3.7 Data Link

Although the detailed flow diagram for data entering the ship-board multi-sensor system via an RF data link is indicated at the uppermost left-hand corner of Fig. 6-3, it has not been the practice to provide a separate channel in such links for ELINT data. One reason for this is the fact that ELINT data has been included in the data block recorded on the sensor imagery and has been scanned off and transmitted as a portion of data. If the link were to be used, a duplicate of the airborne magnetic tape would be made in the Data Link Image Converter and used in place of the actual airborne tape. A separate plotting board could be used especially for the real time display, as indicated in the upper right-hand corner of Fig. 6-3 near the PRIORITY ANALYST, but this has not been done in existing systems. It may be noted in Fig. 6-3 that the duplicate tape produced by the data link system must be processed by the ELINT REDUCTION and COMPUTER equipment before its outputs can be displayed or plotted.

SPECIAL HANDLING

SPECIAL HANDLING